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INNOVATION CONFERENCE-GHANA 2016 PROCEEDINGS

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INNOVATION CONFERENCE-GHANA 2016

PROCEEDINGS

Theme:
Development Innovation –
Putting The Pieces Together

27TH-28TH SEPTEMBER 2016
LA PALM ROYAL BEACH HOTEL, ACCRA-GHANA

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LA PALM ROYAL BEACH HOTEL, ACCRA-GHANA

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Mr Masahudu Fuseini	Research Scientist, CSIR-STEPRI
Dr Rose Omari	Senior Research Scientist, CSIR-STEPRI
Mr Paul Boadu	Research Scientist, CSIR-STEPRI
Mrs. Melody Boateng	UNESCO Ghana

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FOREWORD

The development challenges facing Africa are daunting and yet surmountable. From food and nutrition insecurity, through shelter and unemployment to environmental degradation, the key to addressing the challenges, is Science, Technology and Innovation (STI). In this regard, it is critical to create a climate for innovation that enhances productivity in all sectors of the economy with significant impact on society. Such an innovation climate will nurture Research and Development (R&D) to become the game changers in national development.

Nevertheless, creating and sustaining an innovation climate calls for strong partnerships among all stakeholders especially between government, industry and research institutions. This underpins the exciting prospect of building "Champions of Innovation Network" to rejuvenate the ecosystem of innovation. An economy that is fully geared to new knowledge, technology and innovation, offers enormous potential in promoting economic growth, creating jobs and finding solutions to major developmental challenges. Such a system transforms the productive sectors of the economy, emphasising value addition of raw materials through industrialisation resulting from increased innovation and knowledge generation.

As we make efforts to generate knowledge and stimulate innovation in the country, there is need to create platforms to inform, educate and critique what have been done. We are delighted to publish the proceedings of the first Innovation Conference Ghana 2016, which counts as a platform for innovation discourse. It was the first innovation conference of its kind with very good participation from researchers in a wide range of disciplines. The conference was aimed at creating a network of innovation practitioners, including scholars in order to drive innovation research in Ghana and West Africa as a whole to facilitate socio-economic development and improve livelihoods.

The organizers of this conference and their sponsors would definitely take pride in hosting participants from diverse expertise and across the globe. A greater pride comes with the publication of the proceedings. The knowledge that was produced out of the conference is now permanently documented.

We hope to continue the collaboration in the future.

Dr. Victor Agyeman, Esq.
Director General
Council for Scientific and Industrial Research
Accra

INTRODUCTION

Science, Technology and Innovation (STI) has been identified as the key tool for moving the world into a sustainable growth path[1]. Unlike the developed countries that are more adept at transferring scientific and technological progress into innovative products and services of high commercial value, developing countries are now trying to find space in the innovation paradigm shift. STI is a fundamental tool to implement the new SDGs agenda, as it allows for improving resource efficiency in three key dimensions of sustainable development - economic, social and environmental. The transition towards a sustainable path of development requires participation of all stakeholders including academics, research, business and policy makers in the innovation for development agenda.

From a broader perspective of innovations beyond high-tech, one would say that African economies have been driven by innovations although at a slower pace. According to Figueiredo (2006), our knowledge about innovation in developing country firms has been constrained by the fact that the available evidence has been overwhelmingly qualitative in character, creating problems for comparison and generalization. Studies have shown a significant and positive correlation between innovation and exports for socio-economic development (Barasa et al., 2016; Love & Roper 2015). There are evidence showing that for example, innovations in the Services and Agricultural sectors have greatly impacted on economic development (Tim et al., 2015; Sanyang et al., 2016).

To our minds, research on innovation studies and practical experiences in all sectors of African economies have been widespread. It is against this backdrop that the CSIR-STEPRI in collaboration with AfricaLics, GlobeLics and other partners organized an International Innovation Conference on the theme: *Development Innovation: Putting the Pieces Together*. The two-day event was held on 27-28th September 2016 at the La Palm Royal Beach Hotel, Accra Ghana. A total of 92 relevant stakeholders along the innovation value chain attended the conference. Participants and facilitators were drawn from various countries including Ghana, Burkina Faso, Nigeria, Tanzania, Greece, South Africa, Denmark, UK and USA.

Primarily, the conference aimed at facilitating the institutionalisation of a network of innovation practitioners especially innovation scholars and provided a platform for both scholarly debate and practical experience sharing in the subject area of development innovation. A total of 23 papers presented at the conference have been professionally reviewed and compiled in this conference proceedings.
This proceedings is structured along the four main themes discussed during the conference including:

(i) *Defining innovation practice in Africa-principles and fundamentals;*
(ii) *The nexus of innovation and entrepreneurship;*

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1 *European Commission, Directorate-General for Research and Innovation, Expert Group Report on The role of STI policies in the Implementation of SDGs , 2015*

(iii) *stimulating innovation in the key sectors of economy –what is to do and how to do it; and*
(iv) *Enhancing the manufacturing sector through products innovation.*

Papers presented under the theme "*Defining innovation practice in Africa-principles and fundamentals*" covered areas such as evidence based policy, innovations by local farmers, financial systems for agricultural innovations and innovations in traditional medicine.
Under *"The Nexus of innovation and entrepreneurship"* theme, papers presented include institutional entrepreneurship for innovations in agricultural value chain, gender perspectives of innovations and inclusiveness in development economies, challenges and options of innovation research in developing economies, innovations for sustainable development and innovations in the mushroom industry.
The theme on "*Stimulating innovation in the key sectors of the economy*" has papers on innovations in rice production, soil fertility management, yam post-harvest management practices and development of innovative construction materials from clay and rice husks as well as utility of staple grain logistical platforms.
Lastly, *"Enhancing the manufacturing sector through product innovation"* theme covers papers on physicochemical and quality characteristics of the CSIR-OPRI virgin coconut Oil, genetically modified foods, reducing tar in smoked meat products, use of solar screened drying technology for meat and fish preservation, mechanized palm kernel shell separation, gas cabinet drying of mangoes, hydrolysis and fermentation of Ghanaian green seaweeds for bioethanol production and managing moisture in cereals & grain to reduce post-harvest losses.

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PART 1: DEFINING INNOVATION PRACTICE IN AFRICA-PRINCIPLES AND FUNDAMENTALS

MECHANISMS FOR STRENGTHENING EVIDENCE-BASED POLICY AND PRACTICE: EXPERIENCES FROM THE DRUSSA POLICY FELLOWSHIP PROGRAMME

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Abstract

Evidence-based policymaking is an approach that helps people make well-informed decisions about policies, programmes and projects by putting the best available evidence from research at the heart of policy development and implementation. However, many factors limit evidence-based policy-making both at an individual and organisational levels. Nevertheless, it is imperative not for both policymakers and researchers to improve the availability and dissemination of sound research. This will be achieved by setting up mechanisms that will facilitate greater use of evidence by policymakers. This paper reviewed literature to understand mechanisms for bridging research-policy and practice gaps and appraised the DRUSSA Policy Fellowship programme to determine which of the mechanism were applicable and how this might enhance research-policy and practice linkages in the agricultural sector in Ghana. The paper drew lessons from the author's personal experiences as a past DRUSSA Policy Fellow.

Keywords: *Evidenced-based policy making; Research-policy linkages; Mechanisms; DRUSSA Fellowship*

Background

Evidence-based policymaking is an approach that helps people make well informed decisions about policies, programmes and projects by putting the best available evidence from research at the heart of policy development and implementation (Pew-MacArthur, 2014). It uses the best available research and information on program results to guide decisions at all stages of the policy process and in each branch of government. It identifies what works, highlights gaps where evidence of program effectiveness is lacking, enables policymakers to use evidence in budget and policy decisions, and relies on systems to monitor implementation and measures key outcomes, and uses the information to continually improve program performance.

The word "policy" is not a tightly defined concept but a highly flexible one, used in different ways on different occasions. Webster's dictionary has several closely related definitions. They are:

- A definite course or method of action selected (by government, institution, group or individual) from among alternatives and in the light of given conditions to guide and, usually, to determine present and future decisions.
- A specific decision or set of decisions designed to carry out such a course of action.
- Such a specific decision or set of decisions together with the related actions designed to implement them.
- A projected programme consisting of desired objectives and the means to achieve them.

In English usage, policies are “made” and “implemented” in the same way that decisions are made and implemented. Yet it is possible to have policies that are not or cannot be implemented, so that, conceptually, actions that implement policies need not necessarily be part of policy itself (ILRI, 1995). A policy is a set of coherent decisions with a common long-term purpose. Government policies are often supported by special legislation. Policies are usually national policies (not district or provincial) and are not normally limited in time (ILRI, 1995).

Problem Statement

In fact, policy and practice that are based on research evidence are seen to produce better outcomes e.g. saving lives and improving development performance. However, policy development and implementation are still often weakly informed by research evidence thus creating a wide gap between research and policy. On the one hand, research aims to investigate, learn and produce knowledge by gathering information, contemplation, trial, and/or synthesis. In development context, that may involve action-research or academic study ranging, as examples, from a pilot project, to a laboratory experiment, a consultation exercise, a quantitative survey, a literature review, participant observation or a participatory evaluation, it might be led by beneficiaries, development practitioners or academics from scientific and social science disciplines. On the other hand, policy aims for continuity or change of a practice, including plans and their evolution when put into practice (that is, the ‘how’ as well as the ‘what’ of decisions (Shankland, 2000)).

According to Stone (2001), the wide research-policy gap is due to various reasons including:

- Inadequate supply of, and access to relevant information;
- Need for speedy responses;
- Political expediency and the fact that politicians are rarely scientist;
- Lack of consensus among researchers and policy makers;
- Researchers’ poor comprehension of policy process and unrealistic recommendations;
- Inadequate capacity among policy makers to use evidence;
- Ineffective communication of research;
- Politicisation of research, using it selectively to legitimise decisions;

- Time lag between dissemination of research and impact on policy; and
- The fact that research is deemed unimportant, censored or controlled

Why bridge research-policy gap?
The uptake of research evidence in the policy making process has become the front burner of global discourse on approaches and strategies for development. It is therefore not surprising that international development agencies and other research funders are placing increasing emphasis on the need to communicate research evidence to policy makers. This has resulted in a flurry of activities aimed at supporting the communication of research evidence to policy makers. For example, a study commissioned by UNESCO in Tanzania in 2002 assessed the research – policy linkages of science-related ministries and their research organizations with the objective to understand mechanisms for interacting with policymakers and users of research outputs. In the agricultural sector in Ghana, the USAID Agriculture Policy Support Project is being implemented with the purpose of increasing the capacity of the Government of Ghana (GOG), the private sector, and Civil Society Organizations to implement evidence-based policy formation, implementation, research, and advocacy, and perform rigorous monitoring and evaluation of agricultural programs implemented under the Medium-Term Agriculture Sector Investment Plan (METASIP). Other example is the conference organized by the World Bank Institute in 2008 in Tanzania on the Theme "Practicing Agricultural Innovation in Africa -A Platform for Action". At this conference, a side event on the sub-theme "Bridging Agricultural Innovation to Policy" was organized in which I made a presentation on the topic "Agricultural technology adoption and related policy issues in Ghana.

Furthermore, a number of international development organizations have research programmes aimed at understanding the links between research and policy. These include (1) the Global Development Network that recently started a three-year international research programme to explore research-policy linkages; (2) the International Development Research Centre (IDRC) (Canada), which is undertaking a strategic evaluation of the influence of IDRC supported research on public policy; (3) International Food Policy Research Institute (IFPRI) that undertook impact assessments to measure the policy impact of its research programmes, and how it could be improved. Also, the UK evidence-based policy became the central theme of the Centre for Management and Policy Studies, established by the Cabinet Office in mid-1999. In the same year, the Economic and Social Research Council established the Evidence Based Policy and Practice Initiative, a collaborative network of seven research units aimed at bringing social science research much nearer to the decision-making process.

While efforts are being made to devise mechanisms for bridging research-policy gap, it should be noted that policymaking is inherently a political process. Hence, many factors jostle with evidence to take centre stage in policy formation both at an individual level and at an organisational level. For example, time constraints will affect the mechanisms available to mobilize evidence – urgent issues require different approaches than processes to develop strategic policy directions.

Background to the DRUSSA Policy Fellowship Programme
The Development Research Uptake in Sub-Saharan Africa (DRUSSA) programme seeks to (1) raise the level of discussion around research evidence at senior ministry levels, (2) equip technical staff with practical skills and (3) support senior civil servants as they begin to encourage a culture of evidence-informed approaches to policy making and policy implementation. It was implemented by the CSIR-Science and Technology Policy Research Institute in Ghana in collaboration with the Institute of Statistical, Social and Economic Research (ISSER) of University of Ghana, Uganda National Council for Science and Technology (UNCST) and the Economic Policy Research Centre (EPRC) at Makerere University, and the Association of Commonwealth Universities (ACU) with funding from DFID, UK. In Ghana, the programme was implemented in the Ministry of Food and Agriculture (MoFA), Ministry of Trade and Industry (MOTI) and Ministry of Environment Science, Technology and Innovation (MESTI).

The DRUSSA project has three main components namely, (1) policy symposia for senior officials on 'key debates; (2) professional development courses on 'handling science and evidence' for junior and mid-level policy advisors and; (3) an early career policy fellowship scheme. This paper focuses on the third component, that is, the policy fellowship programme.

The DRUSSA Fellows must possess PhD degree, minimum of three years' research experience and, ideally, should have experience engaging with policy making institutions. After a selection interview with a panel, the successful candidates are placed in one of the participating ministries as policy fellows where they are expected to work closely with policy makers in the selected ministry to facilitate the inclusion of academic research in policy development, and to contribute to forging stronger links between academia and policy makers. The goal of the programme is to improve the accessibility and utilisation of locally relevant research evidence to inform development policy and practice. The fellow then develops a one year (part-time) or 6 months (full-time) work plan that is aligned to the ministry's or department's work plan. The fellow is then assigned a mentor who directly supervises him/her. Both the fellow and the mentor are given monthly allowance however, DRUSSA provides no funds for the fellow's activities in the ministry– the ministry is supposed to fund the activities.

Objectives of the paper
The objective of this paper is to review literature to understand mechanisms for bridging research-policy gap and to appraise the DRUSSA Policy Fellowship programme to determine which of the mechanism are applicable and how this might enhance research-policy and practice linkages in the agricultural sector in Ghana. The paper is based on the author's experience as

a DRUSSA Policy Fellow attached to the Women in Agricultural Development Directorate of the Ministry of Food and Agriculture in Ghana.

Relevance of the review

This review is relevant because it enables the author to draw lessons and make recommendations for enhancing research-policy and research-practice linkage particularly in the agricultural sector. It is acknowledged that without research outcomes many innovations in the agricultural sector could not have been realised or would have come much later (Mansfield, 1991; Beise and Stahl, 1999). It has been established that public research institutions and their interactions with policy makers and users of research results play a central role in the creation and diffusion of knowledge in any system of innovation (Cooke, 2001, Charles, 2003). The research and development (R&D) institutions were expected to provide the structured application of STI to boost the competitiveness of agricultural and other economic sectors. Therefore, deploying R&D is critical for raising agricultural productivity and value chain development for improved socio-economic development in Africa. Agricultural Research and Development is the driving force behind the agricultural productivity revolutions that have helped to transform the economies of developed and some emerging countries such as Brazil, China, India and Thailand. However, this has not been the case in Ghana because a wide gap still exists between research and policy and research and practice. Bridging the gap between the national research system and policy and practice has become crucial in this globally competitive era. Research-policy and research-practice linkages allow for exchanges that enhance understanding of the technological needs among local industries, and capitalise on innovative options to harness and exploit local research outputs for business solutions. In addition, such interactions encourage research and innovation in areas of relevance for the agricultural sector and private sector growth.

Literature review

Models for bridging research-policy gap

To overcome the stumbling block for linking evidence into policy, innovative models are needed. Weiss (1979) proposed seven models of research-policy linkage namely, knowledge-driven model, problem-solving model, the interactive model, the political model, the tactical model, the enlightenment model, and research as part of the intellectual enterprise of the society. This framework has been widely used and adapted by subsequent writers (e.g. Nutley et al., 2002; Nutley & Webb, 2000; Young et. al., 2002). Others have adopted a simpler framework contrasting the two 'ideal types' of research utilisation: the engineering model and the enlightenment model (Bulmer 1982; Nutley & Webb 2000). Landry et al. (1999) propose a different approach involving four models: the technological model ('science push'); the economic model ('demand pull'), the institutional model (focus on dissemination processes), and the social interaction model (focus on relations between researchers and policy makers). While these models have their strengths and weaknesses, Jones and Seelig (2004) distinguished three broad models namely, the engineering model, the engagement model and the enlightenment model, which largely reflect most of the characteristics of the previous models. The models proposed by Jones and Seelig (2004) present alternative conceptions both of how research actually links to policy and of how it should link that is, they are both explanatory and normative models. The characteristics of the three models are shown in Table 1.

Table 1: Models of research-policy linkages

Characteristics	Engineering model	Engagement Model	Enlightenment Model
Type of linkage	Linear	Interactive	Indirect
Purpose of research	Problem solving	Policy development	Social progress
Type of research	Applied	Policy research	Basic, discipline research
Orientation to policy	Technocratic	Participative	Skeptical
Consensus on goals	High	High or moderate	High, moderate or low
Role of researcher	Technician	Collaborator	Social critic
Role of policy maker	User	Collaborator	Target
Research-policy relations	Contractual	Partnership	Detached
Research beneficiary	Policy-maker	Policy network	Society
Dissemination mode	Targeted	Networks	Percolation

Jones and Seelig (2004)

The **engineering model** of research-policy relations encompasses the 'knowledge-driven' and 'problem-solving' models in Weiss's typology (1979), and the 'technological' model in the formulation by Landry et al. (1999). In this model, the link between research and policy is essentially linear: 'a problem exists; information or understanding is lacking either to generate a solution to the problem or to select among alternative solutions; research provides the missing knowledge; and a solution is reached' (Bulmer, 1982:42). The purpose of research is primarily to assist in solving policy problems by providing relevant empirical evidence and conclusions (Weiss, 1979). The definition of the policy problem is mainly the responsibility of the policy or decision-maker. The assumption is that decision makers have a clear idea of their goals and their information needs, and they engage social scientists to provide data, analysis and interpretation of research findings. In the engineering model, the focus is on applied research, that is, the research is driven primarily by the needs of the intended users, and is centered on a specific problem or set of problems. In this model, the role of the researchers is primarily technical, that is, providing the evidence and conclusions to help solve a policy problem. The policy-maker commissions the research to fill knowledge gaps and is the end-user of research findings. Thus, the relations between researchers and policy-makers are often contractual. The model demonstrates clearly how policy-makers seek 'answers' from research for the development of evidence-based policy however, it is widely criticised as simplistic and wildly optimistic (Jones & Seelig, 2004).

The **engagement model** of research-policy relations encompasses the 'interactive', 'political' and 'tactical' models in Weiss's typology. In this model the linkages between researchers and policy-makers are portrayed as interactive, complex and multi-dimensional. In this model, the purpose of research is to bring the distinctive knowledge, skills and values to bear on policy issues, through ongoing engagement and interaction of researchers and policy-makers. The type of research can be basic or applied, but is characterised above all by its commitment to policy-relevance. The engagement model is inherently political hence researchers need to understand and take account of this political environment. This model clearly demonstrates that research can play a key role in policy development, but this is contingent on many factors and circumstances, including the political skills of researchers who can themselves sometimes become influential figures (Young et. al. 2002). Thus, policy-makers interact with researchers out of a commitment to research-informed policy. While researchers and policy makers have distinctive roles and positions in policy processes, their relations are often characterised by collaboration and partnership, and moderate to high levels of consensus on policy goals. Researchers also seek to develop links with interest groups and the media, as these groups are important in bringing research findings to the attention of policy-makers (Weiss, 1986). Researchers need to be both committed to the values and methods of research and capable of engaging effectively in the world of policy and politics. Policy makers need to be not only responsive to the political environment but also receptive and open to the findings and implications of policy research (Jones and Seelig, 2004). The major criticism of this model is the dangers of the politicisation of research and the development of somewhat complacent 'policy communities' comprising researchers and policy-makers of similar views.

The **enlightenment model** encompasses the 'enlightenment' and 'intellectual enterprise' models in Weiss's typology, and reflects the longstanding liberal-democratic tradition that emphasises the importance of the independence of academic research (Hammersley, 2000; Wilensky, 1997). In this model of research-policy linkages, relations between researchers and policy-makers are indirect, and research is undertaken for the benefit not of policy-makers as such but of society as a whole. Research tends to be driven by the theoretical and conceptual framework of academic disciplines rather than by particular policy questions. Research provides the 'intellectual background of concepts, orientations and empirical generalisations that inform policy' (Bulmer, 1982). Proponents point to evidence suggesting that policy-makers often welcome research that challenges prevailing frames of reference and makes them rethink comfortable assumptions (Bulmer, 1982). However, the model pays little attention to the processes linking research and policy. It suggests no strategies for ensuring that the findings of social science research are utilised by decision-makers.

Other means of facilitating research-policy linkages

The models described earlier all lead to the generation knowledge or evidence. However, the way the evidence is presented matters when policy needs to be influenced. An understanding of how different types of research evidence make their way to policy makers would make communications strategies far more effective. Berkout and Scoones (1999) identifies two processes: 'snowballs' (the accumulation of research impacts within policy elites) and 'whispers' (the reinterpretation of research findings in broader constituencies). Saywell and Cotton (1999a,b) have described the process in terms of the **limestone model** (information trickles like water through porous rock), the **gadfly model** (information gets through because dissemination is prioritised as much as research itself), and **insider model** (researchers exploit links with policy-makers). The 'limestone' model is essentially passive requiring nothing more of the researcher than to conduct the research and present findings in a readable way. It is hoped that the findings will gradually seep into the consciousness of the public and decision-makers. The 'gadfly' model involves sporadic, but enthusiastic participation in policy processes, based on a strong commitment to policy and social change. The 'insider' model involves close, continuous engagement with policy processes, and identification with the goals and needs of decision-makers.

Linkages and interactions between researchers and policy makers can be facilitated by mechanisms such as establishing institutional mechanisms that will promote holding meetings between researchers and policy makers for priority-setting exercises, convening national policy dialogues, debates or conferences (Dobbins et al., 2007; Landry et al., 2006). Furthermore, in order to become more familiar with problems that occur in practice or policy making, researchers have to engage in more discussions through collaborative relationships with target users (Haynes, 1990). Policy-makers could also be engaged as a responsible partner in various stages of health system research process, right from setting priority research questions, conducting corroborative research projects, discussing results, knowledge transfer or dissemination, utilization of research evidences in decision making and governance and funding research. Other mechanisms include giving exposure to policy makers to research environment early in their carrier and giving internship opportunities for young researcher into public sector/ health system organizations, whereby they can spend more time understanding the policy making environment (Hanney et al., 2003).

Methodology
This is a review paper hence several documents, as indicated under the reference section, were reviewed. The process involved searching relevant documents online and from different websites and reading them to understand the various mechanisms that can be used to bridge research-policy and research-practice linkages. Information was also gathered on the strengths and weaknesses of the models for strengthening research-policy and research-practice linkages. The author then appraised the DRUSSA Policy Fellowship programme based on her personal experiences as a DRUSSA Policy Fellow to see which of the research-policy models were applicable in the DRUSSA programme and how this might enhance research-policy and research-practice linkages in the agricultural sector in Ghana.

Findings and discussion
Experiences, some activities and achievements as a DRUSSA Policy Fellow placed in the Women in Agricultural Development Directorate of the Ministry of Food and Agriculture
The Fellowship period was quite a learning process particularly in trying to enhance the capacity of the Women in Agricultural Development (WIAD) Directorate to better deliver on its mandates. It was also a challenging moment because of lack of resources to support me implement some of the activities in my work plan. These notwithstanding, some achievements were made as follows;

- Developed training materials and conducted a two-day training for WIAD staff to keep them abreast with current and emerging issues in food safety based on evidence from my research and research from other sources. This training was relevant because among other things, WIAD is mandated to empower farmers, processors and enterprises to produce safe and quality food products for both local and international markets.
- As a follow up, WIAD asked me to prepare an advocacy paper for them to present to the Minister of Food and Agriculture to get the Ministry's increased support for WIAD's work. The advocacy paper contained adequate data and evidence to depict the extent of food safety problem and the need for a sustained solution.
- In relation to WIAD's plan to promote Orange Fleshed Sweet Potato (OFSP) as a source of vitamin A and to develop their capacity in nutrition-sensitive agriculture, I made a presentation at a policy dialogue on the topic *"Combating micronutrient deficiency through nutrition-sensitive agriculture: Implications for food and agricultural policy"*. The presentation was used to advocate for increased budget and logistical support for WIAD to implement their nutrition-sensitive agricultural activities. A policy brief is being prepared for submission to the Ministry.

- To assist WIAD get some funded projects, I facilitated the development of a joint proposal between WIAD and Raw Material Research and Development Council of Nigeria to source funding from WTO to conduct Training in sanitary and Phytosanitary issues concerning groundnut value chain (outcome is not yet known).

Impact of the DRUSSA Fellowship programme on WIAD from author's perspective

WIAD is a technical directorate so they have all along been working with researchers. WIAD also has a product development and trial laboratory where most new food processing techniques are refined before they are transferred to users. The technical staff of WIAD therefore understand the value of research and have even included in their work plan an activity to seek funding to commission research on soybean utilization in Ghana. In fact, because of their appreciation of the relevance of research, it was quite easy for them to understand the objectives of the DRUSSA policy fellowship programme. As a technical directorate, WIAD would want to see an increased level of collaboration between them and research institutions mainly because they rely on the latter for an up-to-date information for their clients who are mostly women farmers, processors and traders in food products.

Previously, WIAD collaborated mostly with research and development institutions that develop products and technologies. However, due to their involvement in the DRUSSA Fellowship programme, WIAD's participation in policy-related activities has increased. As a result, WIAD Director asked the fellow to give them training in policy analysis, to which the fellow complied. Also, due to the relationship that has been built between the fellow and WIAD staff, the latter often calls the fellow to ask questions and discuss various work-related issues. As the way forward, the fellow will continue to work with WIAD in terms of writing proposals and getting funded projects, and implementing a number of activities in the area of nutrition and food safety. Already, I have facilitated the establishment of an Innovation Platform for Aflatoxin Control in Maize and Groundnuts and WIAD is going to play a significant role when activities commence.

The major strengths of DRUSSA Fellowship programme stemmed from the fact that by being "embedded" in the Ministry, the staff sees the fellow as one of them and are willing to be more open in dealing with him/her. Fortunately, the fellow was placed in the Women in Agricultural Development (WIAD) Directorate of the Ministry of Food and Agriculture where she previously worked for about three years before joining the Research Institute. As a result, it was quite easy working with the WIAD staff most of whom were the fellows former colleagues. The DRUSSA Fellowship programme also had some weaknesses which include: (1) lack of office space for which reason various communication channels including emails, phone calls and text messages, and WhatsApp were used; (2) unavailability of funds for WIAD to carry out most activities in their work plan. This affected the implementation of the fellow's work plan, which was largely linked to the

WIAD's. These notwithstanding, the fellow adopted a strategy by focusing on activities that would require little or no financial resources except time and effort. For example, as part of the fellow's contribution to WIAD's 2016 activity to develop a Work Place Nutrition Policy, the fellow developed a draft policy in which she identified key issues, proposed strategies to address the issues, and then developed an implementation plan. This document would then serve as a working document that WIAD could use when they are ready to develop the policy.

Lessons learnt from the DRUSSA policy programme

- The programme is a learning process particularly for the fellow in trying to enhance the capacity of the Directorate (Women in Agricultural Development) to better deliver on its mandates.
- Future fellows should be sure of availability of necessary resources before they develop their work plans.
- Fellows should be given adequate time to interact with the Ministry staff before being asked to develop and submit the work plan.
- The kind of interactions that has developed between the fellow and WIAD staff is an indication that they have mutually benefitted from the relationship.
- When there is trust between researchers and Ministry staff there will be a cordial and good working relationship. The fellow's desire and ability to respond to WIAD's requests and give them all the needed support has contributed to strengthening the mutual relationship. Thus, building a good relationship is critical for bridging research-policy.

Conclusion and Recommendations

Evidently, no single model may be adequate in effectively bridging research-policy and practice gap hence it may be prudent for researchers to consider which model or combination of models that represents their stance with respect to policy processes. Based on the author's experiences, the DRUSSA fellowship programme uses a combination of models but with emphasis on the engagement model in which linkages between researchers and policy-makers are portrayed as interactive, complex and multi-dimensional. The programme also demonstrates the Insider Model, which involves close, continuous engagement with policy processes, and identification with the goals and needs of decision-makers. The DRUSSA programme facilitates research-policy interaction that can be more sustainable. The fellowship period has been a learning process particularly in trying to enhance the capacity of WIAD to better deliver on its mandates. It was also a challenging moment because of lack of resources to support the implementation of some work planned activities and hence the adoption of various coping strategies.

Future fellows should not be too ambitious when developing their work plan and whenever possible they should explore other sources of funding to enable them implement their plans. These other funding sources could be through proposal writing or other available fund-raising options. The fellows should be selfless and ready to give off their best and in this case, the Ministry will likely chase them wherever they are. One way of improving the Fellowship will be to allocate some small funding for the fellow for implementing some key activities agreed upon by the Ministry. This fund could come from the DRUSSA funds or the participating ministries. The DRUSSA Fellowship programme is useful for both the fellow and the Ministry hence the administrators should sensitise the Ministries to understand the value of the programme so that they can commit some resources to the programme to maximally benefit from fellows' expertise.

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LOCAL INNOVATION SUPPORT MODEL FOR MAINSTREAMING FARMER INNOVATIONS IN GHANA

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Abstract

This write-up describes a model for implementing and scaling up a community-based funding mechanism that provides small funds to innovative farmers to improve and disseminate their innovations. The funding mechanism called Local Innovation Support Facility (LISF) is based on lessons learnt from a piloting exercise in eight countries including Ghana. During the pilot, adoption rate of innovations ranged from 25 to 59% and there was proliferation of interesting innovations. A district model is proposed, in which a non-governmental organisation (NGO) as the coordinator would manage the fund with a District Management Committee comprising representatives from major agriculture-biased development stakeholders including farmer-based organisations. Interested farmers would apply for small funds, which would be granted on merit. A National Coordinating Unit supported by a National Steering Committee would have oversight responsibility of the district-level LISFs. The expanded national programme would be structured into three new zones, namely Northern, Central and Southern Zone. The district-level coordinating NGO in collaboration with the National Coordinating Unit would liaise with Promoting Local Innovation (PROLINNOVA) network and other relevant international partners for mutual support. To increase capacity for scaling up and to enhance sustainability of the LISF approach, three complementary strategies described in this paper would be pursued.

Introduction

Rural small-scale farmers have for long been marginalised in their involvement in and benefit from agricultural research and development (ARD) funds, processes and activities that are targeted at improving their productivity and livelihoods (van Veldhuizen & Waters-Bayer 2013), yet they are very resourceful, have expert knowledge of their local environment and are constantly innovating and searching for solutions to their problems and to take advantage of emerging opportunities (Waters-Bayer & van Veldhuizen 2006). According to IST (2009), local innovation is the process by which people develop new and better ways of doing things using their own resources and initiative. At a World Bank (2004) programme on Indigenous Knowledge for Development, there was a recommendation for the establishment of an innovation fund to promote exceptional indigenous knowledge practices. An analysis and review of five innovation support funds (Friis-Hansen and Egelyng, 2006) culminated in the observation that an institution of a global innovation facility could play a beneficial role in facilitating access to innovations across the globe. Against this background, from 2008 to 2011, the Local Innovation Support Facility (LISF) approach was piloted as part of Farmer Access to Innovation Resources (FAIR) initiative in Ghana and seven other African and Asian countries within the Promoting Local Innovation (PROLINNOVA) network to explore the possibilities of a sustainable community-based funding mechanism to provide small funds to innovative farmers to improve their innovations, to experiment and to stimulate learning. The initiative sought to ultimately empower farmers and create favourable conditions and opportunities for them to play leading and decisive roles in demand-driven research in sustainable agriculture and natural resource management (NRM) to improve food security and livelihoods of rural small-scale farmers (Avornyo et al 2012).

All farmers innovate to some extent, many of them simply to survive. Although farmers have been experimenting informally and developing local innovations to address their livelihoods and agricultural problems over decades, it is only of recent that their innovative capacities and potential have received increased attention of scientists and development professionals (Wettasinha et al 2008).

In Ghana, the FAIR initiative was coordinated by the Association of Church-based Development Projects (ACDEP), as the NGO coordinating the PROLINNOVA–Ghana platform. It was co-managed by the Northern Ghana LEISA[2] Working Group (NGLWG), which was represented by a seven-member core management team. The pilot was implemented in four designated zones namely, Walewale, Bolgatanga, Tamale and Yendi, where local NGOs, MoFA and CBOs formed LISF committees that managed and operated the local funds for small-scale farmers, farmer groups and CBOs. Each LISF zone comprised a number of local government districts/municipals. After significant results were achieved during the pilot activities, it became important to document and consolidate the local experiences and lessons learned into clear feasible models to facilitate the full operation and scaling up of LISFs in Ghana. This paper therefore describes the best and most feasible way to implement and scale up sustainable LISFs in Ghana. It covers the relevant structures at the local and higher levels, decision-making principles, grant-making procedures and monitoring and evaluation (M&E) of the LISFs (Avornyo et al 2012). It draws also from lessons learnt during the LISF piloting experiences in the other seven countries (PROLINNOVA 2012).

[2] LEISA: low-external-input and sustainable agriculture

Methodology

Reconnaissance visits were undertaken in order to gain familiarity with the physical features, the social structures and set-up, the political environment and arrangements, as well as development activities in target locations. Key persons including political leaders, heads of ARD institutions such as MoFA directors and agricultural NGO managers, opinion leaders, chiefs, women leaders and farmer leaders were met to brief them on LISFs and relevance to the local development agenda. District-level sensitisation workshop was then organized for key stakeholders to present the LISF concept and approach, identify opportunities for collaboration and seek their support for LISFs. Next a focused partners' workshop was organized to identify institutions to coordinate the LISF initiative in the district and also the modalities for collaboration. Finally, the LISF was launched and a work plan was developed with identified partners. The work plan was in two sections namely a narrative followed by a matrix. The narrative touched on the geographical coverage of the pilot and the organizational set up of identified partners as well as their agreed roles. Mechanisms for collaboration and capacity building requirements were spelt out. Monitoring and evaluation framework was developed. Institutionalization strategy and dissemination plans were also developed. Activities and budgets for each year were tabulated and together with identified partners, the plans were rolled out in the pilot.

Results and Discussion

The Model

District-based LISF

This is a decentralised model to be operated at the district level where an active NGO will coordinate, manage and implement LISF activities together with an LISF Management Committee. This committee, which will jointly own the LISF in the district, will comprise representatives from major development partners such as NGOs working in agriculture and NRM, relevant government agricultural institutions such as MoFA, research institutes, the Environmental Protection Agency (EPA), already established CBOs and farmer groups that exist and operate in the district or region. Management of LISFs by farmer organisations at some point proved too challenging for farmers in Cambodia but not in Ethiopia and South Africa (PROLINNOVA 2012). The coordinating NGO will be the custodian of funds and its management, and will perform administrative functions including contracting for the programme, programme implementation and reporting to a national coordination.

The LISF Management Committee would make the major decisions for the effective functioning and implementation of the district LISF, including screening and approving farmers' applications; approving action plans, budgets and fund disbursements for LISF activities and grants; facilitating learning and capacity building of partners and farmers; admitting new partners and scaling up to new areas. The coordinating NGO, with guidance and technical support from the district-level LISF Management Committees, would work with local partners such as NGOs, established CBOs and MoFA to implement the activities at community level with farmers and farmer groups. PROLINNOVA–Cambodia had, for example, the active participation of 20 organisations (PROLINNOVA 2012). With regard to fund management, a national coordinating organisation would transfer funds into the bank account of the district coordinating NGOs based on a signed Memorandum of Understanding (MoU) and contract, with approval of PROLINNOVA–Ghana National Steering Committee (NSC). The funds would then be disbursed by the coordinating NGOs for LISF activities and to individual farmers and groups based on plans and applications that have been screened and approved by the LISF Management Committee. With time, LISFs are expected to expand and cover the entire country and operate in three LISF areas – Northern Ghana, Central Ghana and Southern Ghana – while maintaining the same national- and district-level structures and fund management approach. By this time, it is expected that the LISF concept would have been better understood by a wider section of ARD stakeholders who would want to participate or contribute funds to the Ghana Local Innovation Fund.

LISF structure and co-ownership at national level

The proposed LISF structure at national level would be such that a credible Ghanaian NGO would host and coordinate the programme under the authority and oversight responsibility of an NSC specifically for the LISF programme, which would also advise on policy direction and decisions for smooth operation of LISFs in Ghana. This NGO would have ultimate authority for approving plans and budgets for running the overall programme activities and those of the LISF districts or zones. The PROLINNOVA International Secretariat, currently hosted by the Royal Tropical Institute (KIT) in the Netherlands, would provide networking assistance to the PROLINNOVA–Ghana for effective implementation and updates on new global developments and issues. The NSC for the LISF programme would be composed of senior persons from key national agricultural and research institutions, development NGOs and national farmer organisations. The proposed composition of the committee of eleven members would be drawn from the national coordinating organisation, MoFA, CSIR, a university, an NGO, a national farmer organisation and EPA. PROLINNOVA–Cambodia on the one hand, uses an NSC membership of five officers who also engage in the screening of proposals (PROLINNOVA 2012), while PROLINNOVA–Uganda has proposed to make use of a national farmer organisation to host and manage the LISF programme (van Veldhuizen & Waters-Bayer 2013). The aforementioned countries provide useful lessons for the Ghana platform in the mainstreaming of Prolinnova nationwide. PROLINNOVA–Ghana would also collaborate with Ghanaian agencies and other national and international agencies to source resources to build up a Ghana Local Innovation Fund.

Division of tasks and roles between the national and local structures

The basic and clear distinction in roles and tasks is that the national structure will focus on policy issues, programme development, sourcing funds, quality control, capacity building, facilitating networking among the various LISFs and other stakeholders, and representing the programme at national and international levels. On the other hand, the local structures will be concerned with operating or implementing an efficient and cost-effective LISF programme at the community level to achieve improved productivity, food security and livelihoods of rural farmers in an environmentally sustainable manner. This includes training, community sensitisation, identifying and assisting farmer innovators, documentation, and creating learning and experience-sharing opportunities for farmers and local partners.

Description of the LISF Process

This description of the LISF process is based on experience made with LISFs in northern Ghana, enriched by experiences in the other seven countries where LISFs were piloted during the FAIR initiative.

Call for proposals

To begin the LISF process, a call would be made for submission of suitable proposals. Information would be provided to aid the submission of proposals. Prospective applicants' capacities need to be built to increase the number of very good proposals submitted, as was done in Cambodia, Ethiopia and Nepal (PROLINNOVA 2011). Calls would also be made on radio programmes and other platforms, and these calls would be extended by local CBOs as well as by other partner organisations such as MoFA and selected NGOs at farmers' fora and community meetings. In Nepal, calls were made in national newspapers and on an FM radio station. South Africa instituted farmers' fora where farmers met to exchange knowledge and information about local innovation (PROLINNOVA 2012). Application forms would be lodged with district coordinating institutions for access by CBOs and other partner organisations. Applications would be submitted by interested farmers to both partner organisations and selected CBOs for onward submission to the district coordinating institution. A date would be set for vetting of proposals.

Persons eligible to submit proposals

If the proposal satisfies set criteria, then the innovator could apply through his/her CBO or partner organisation to the LISF. Farmer innovators who belong to a recognised registered CBO with a financial (bank) account with a recognised bank could submit individual or group proposals. There should be evidence that the financial accounts of submitting organisations have been audited. Alternatively, farmers could submit proposals through MoFA as well as recognised NGOs with certificates of incorporation, registration and/or to commence business. The innovator must demonstrate capacity to undertake the proposed innovation/experiment. Women would be particularly encouraged to submit proposals.

Screening and selection of proposals

Using some selection criteria, the LISF Management Committee would screen applications at district level. Next, the district coordinating institution would organise a feedback workshop to communicate the outcome of the applications. The qualified applications would then be forwarded to the national coordinating institution for final approval and release of funds. Data on the application forms would be entered into a register at the district level and collated at the national level.

Criteria for screening proposals

All implementing districts would use the same set of criteria for vetting proposals to ensure fair and objective assessment, selection and fund allocation to the most eligible applicants. Therefore, the content of each proposal would be subjected to the following basis to qualify for selection:

1. The TEES (Technical, Economic, Environmental and Social viability) test (Critchley 2007)
2. The innovation for which the application is made is locally evolved and developed using local knowledge
3. It is addressing immediate local needs or long-term solutions or opportunities
4. It can be easily adapted by another individual or farmer groups
5. It involves the use of easily available/accessible local resources
6. It is a social innovation or an innovation from a woman/women
7. It is addressing a theme not covered by many applications
8. It is likely to receive approval of the District, Municipal or Metropolitan Assembly where the innovation would be tested
9. Amount requested does not exceed the ceiling set by the management committee; if it does, the applicant may be asked to review his/her budget or the application may be disqualified (Avornyo et al 2012).

Disbursement of funds

Following final endorsement and approval, funds would be transferred to district LISFs through their established bank accounts. The funds may be paid to the innovators in one or several instalments. In Cambodia, the funds were given out as loans to serve as a revolving fund for farmer groups to allow continuous experimentation by farmer innovators (PROLINNOVA, 2012). PROLINNOVA–Uganda also experimented with the revolving fund concept but it was not successful (PROLINNOVA, 2012). The revolving fund approach might have more potential for growth and sustainability of the LISF process.

Type of activities to be supported by LISFs

The money could be used to cover travel costs (learning or exchange visits, allowances and transportation) and operational costs including communication, consumables, training as well as disposable materials and equipment. The following activities would be eligible for funding: farmer's own experimentation in which the innovator leads the research and applies part of the funds to cover the fuel costs and time of researchers for technical support and joint learning; farmer-led documentation; joint experimentation with MoFA and research institutions, for which related costs are included in the LISF application; learning visits and training and Farmer Field Schools. In Ethiopia, innovations which sought to address priority problems facing a large number of farmers in the area were targeted for funding (PROLINNOVA, 2012) and Ghana can draw useful lessons from this approach. Requests for micro-credit, large capital items and means of transport, and infrastructure development that are not innovations would not be accepted. In the application form, applicants would be requested to indicate their own contribution or other sources of funds. If the proposal is not for making profit and the applicant is willing to share his/her results, then the applicant would be eligible for a grant.

Programme Monitoring Approach

Innovations would be implemented and validation would be by farmers, researchers and other development workers. Innovations would be monitored and evaluated by the innovators themselves, CBOs, partner organisations, district team, focal person, NSC, national coordinating institution and consultants (see Impact assessment methodology). Each district LISF committee would hold quarterly meetings to review progress and plans. However, during the implementation of activities such as screening of proposals, disbursement of funds and report writing, additional meetings would be organised.

Monitoring and evaluating the functioning of the LISFs

District coordinating institutions would monitor the functioning of the LISF by completing the LISF register that was tested and refined during the FAIR initiative. This register software is based on MS-Access and used for LISF M&E and administration. Things that would be monitored and evaluated include the personal details of applicants, proposed topics and activities, screening results, fund disbursement, fund utilisation, transaction time and costs, reports, timely delivery of results, follow-up activities, extent of farmer involvement in managing the LISF and degree of sourcing financial resources for the LISF. There would also be monitoring of the percentage of applications approved as compared to the number planned for the year by the district coordinating institution. Suggestions would be made for the improvement of the programme.

The national coordinating institution would carry out M&E of the entire programme, including M&E of the LISF structure and governance. Both the district and the national coordinating institutions would monitor capacity-building activities undertaken. They would also monitor the planning and review meetings, operation of bank accounts, monitoring exercises and submission of reports.

Impact assessment methodology

Impact assessment would be done occasionally in a few selected districts implementing LISFs. Competent consultants would be contracted to conduct the impact assessment. It would start with designing the impact assessment guideline and instrument. An activity plan for the impact assessment would also be drawn up, including timelines and roles among partners. Secondary data would be used to help in identifying the innovations, the level of innovation development and the location of the various innovations. This would also help in identifying the institutions involved and all LISF-related activities. Pre-testing of the assessment guideline would be done in the innovation communities. After completion of the interviews and focus group discussions, multi-stakeholder workshops would be organised to share the results with the LISF stakeholders.

Some outcomes during piloting

During the piloting, it was realized that farmer innovators had gained self-recognition and had also made extra income to feed their families, school their children and engage in petty trading. Improvement in the quality and numbers of animals led to enhanced income from the sale of healthy animals and more manure for their farms leading to increased crop yields and reduced hunger at the household level. Farmers' ability to buy farm inputs such as fertilizer increased and ability to pay for health insurance for family members also improved. Some farmers were also able to purchase bicycles as a result.

The fund had rekindled interest of the community members to be innovative in their activities. As a result, there was proliferation of innovations as farmers were trying new things and flow of information had increased. Even though there was a high level of illiteracy making understanding of the FAIR concept difficult at the initial stage, frequent interactions with farmers improved their understanding and thereby improving the quality of proposals that were subsequently submitted. Low female participation was observed probably because of low female representation at management level.

Most of the activities emanating from the LISF were also found to be beneficial to the environment and had higher adoption rate compared to other agricultural technologies. Adoption rate of between 25% and 59% was estimated during the piloting.

Scenarios and Strategies for Scaling up LISFs

Recommended process of introducing and launching LISFs in new areas/districts

LISF introduction and implementation could be successful if a number of conditions and criteria are met and if a carefully designed step-wise introduction process is taken, as detailed below.

Criteria for selecting new areas or districts to start LISF implementation

For an LISF to function successfully and yield expected results, the following conditionsshould exist. These form the criteria for selecting districts to participate in the programme:

1. Availability and willingness of a trustworthy, credible and reliable local NGO with experience and understanding of farmer-led agricultural development to host and coordinate the LISF programme
2. Availability of partners committed to farmer-led agricultural development to support implementation of the LISF activities and willing to participate in all the activities, including capacity building, planning and reviews at district and national level, sharing experiences and results, joint field monitoring and learning visits
3. Commitment of partners' resources to support LISFs and also mainstream the LISF into their rural development programmes in agriculture, NRM and livelihoods improvement as well as complement or add value to the LISF fund and activities
4. Availability and interest of strong CBOs and farmers including potential innovators to engage in local innovation and farmer-led experimentation to improve and sustain their productivity and livelihoods
5. Willingness of innovators and CBOs to share their innovations and outcomes with other farmers and development collaborators
6. Peaceful areas or districts free from political, ethnic and social conflicts and unrest that can negatively affect or disrupt LISF work or development work in general.

Process for selecting a new district for launching LISF

The sequential steps for selecting a new area or district to introduce an LISF are as follows:

- Undertake preliminary reconnaissance visits to become acquainted with the physical features, social structures and set-up, political environment and arrangements, as well as development activities
- Meet key persons of authority and influence personally including political leaders, heads of ARD institutions such as MoFA directors and agricultural NGO managers, opinion leaders, chiefs, women

leaders and farmer leaders to brief them on LISFs and relevance to the local development agenda and solicit their support and cooperation

- Organise district-level sensitisation workshop for key stakeholders, including community and farmer leaders, to present the LISF concept and approach, and to understand major development issues, identify opportunities for collaboration and seek support for LISFs
- Identify key and interested development partners to collaborate and participate in the programme; present the goal, objectives and approach; and elicit expectations from the partners at a focused partners' workshop
- Identify and select the institution to coordinate the LISF initiative in the district, hold meetings with this institution to discuss modalities for collaboration and to secure firm commitment, and sign partnership agreement
- Support/collaborate with the coordinating institution to launch the LISF with key stakeholders, including political leaders, farmer leaders and the potential partners.

Conclusion

For setting up an LISF, there should be reconnaissance survey and key stakeholder meetings to identify a local NGO with experience in farmer-led agricultural development to host and coordinate the LISF, as well as committed partners including farmer groups to support implementation of the activities. Innovators should also be willing to share their innovations. The LISF would operate a decentralised model at the district level, where the local NGO would coordinate and implement LISF activities together with an LISF Management Committee. The district coordinating NGO would enter into a partnership with a national coordinating organisation equipped with a constituted National Steering Committee. The local structures would be concerned with implementing the LISF programme at the community level while the national structure would focus on policy issues, programme development, sourcing funds, quality control, capacity building, facilitating networking and representing the programme at national and international levels. The LISF process would begin with a call for proposals followed by vetting of proposals. Qualified applications would be forwarded to the national coordinating institution for final approval and release of funds. Data on the application forms would be entered into a register at the district level and collated at the national level. To ensure the LISF approach is sustainable in the long term and scaled up, it is proposed to integrate it into the MoFA extension system, the local government system or operate as an NGO-led programme.

Policy recommendation for scaling up LISF

Proposed scenarios for scaling up and institutionalising LISFs in Ghana
The following three complementary strategies are proposed to be explored, developed and implemented to scale up and institutionalise LISFs in Ghana:

1. Integrating into MoFA extension
2. Establishing LISFs as an NGO-led programme
3. Integrating into local government system.

Integrating LISFs into Ministry of Food and Agriculture

The Ministry of Food and Agriculture (MoFA) is responsible for formulating and implementing national agricultural development and food security policies and programmes in Ghana. The programmes and policies are delivered by regional and district/municipal/ metropolitan MoFA directorates through various units such as Extension, Crops, Animal Production, Veterinary, and Women in Agricultural Development.

If the LISF were integrated into MoFA, a Farmer Innovation Unit would be created at both regional and district offices and overseen by a fully dedicated staff member from the extension unit. He or she would liaise actively with the regional and district Research-Extension Liaison Committee (RELC) coordinators for effective integration and harmony. MoFA would be required to contribute part of its central government budget allocation and other allocations from special projects into the LISF fund to support farmer-led experimentation and innovation activities.

Farmer innovators and NGO LISF partners would participate in RELC meetings together with MoFA and the research institutions and would report on the activities and outcomes of LISF activities. Additionally, national farmers' awards would include best innovators at the district- and regional-level events in order to promote the concept and encourage local innovation and farmer-led initiatives in agriculture. West African Science Service Centre in Climate Change and Adapted Land Use (WASCAL) instituted farmer innovation contest in the Upper East Region of Ghana where some deserving farmers received various awards (Wunscher, 2013). In South Africa, innovation markets are held occasionally to give farmer innovators opportunity to share their innovations with the wider public (PROLINNOVA, 2012). Hence, RELC would provide an avenue and opportunity for sharing information on LISF activities and outcomes as well as enhancing and encouraging scientific testing and validation of the best farmer innovations by agricultural extension experts, managers and researchers. This is expected to ultimately influence ARD programmes and approaches in favour of an LISF approach and promoting farmer innovation.

The LISF approach and promoting farmer innovation would also be made a major agenda issue for regular monthly regional MoFA review and planning meetings for district MoFA directors. Local innovations and processes of supporting farmer innovation would be reported at monthly MoFA review and planning meetings for district MoFA directors by tasking agricultural extension agents to capture innovations and innovation processes in their respective zones and also by involving the district directors in innovation development activities in their districts.

Establishing LISF as an NGO-coordinated programme

This appears to be the most feasible scenario to start with. The LISF programme would be hosted at the national level by an NGO that would act in the capacity of a national coordinating institution. This institution would allocate funds to support the programme. Some of the strategies it would adopt include the constitution of an NSC with members drawn from the headquarters of the Ministry of Environment, Science and Technology (MEST), MoFA, Ministry of Local Government and Rural Development (MLGRD), a dynamic national farmer organisation, the Council for Scientific and Industrial Research (CSIR), EPA, the Forestry Commission, a university and an NGO. The members of the NSC would be officers who are capable of influencing national policy, thereby increasing access to government resources for promoting farmer innovation. In Nepal, for example, the Deputy Director-General of Department of Agriculture was made the chairperson of the national-level LISF committee, which was mandated to coordinate their PROLINNOVA initiative; other members included a person from their National Agricultural Research Council (PROLINNOVA, 2012). The national coordinating institution would enter into an alliance with NGOs or projects that share in the farmer-led innovation development and research agenda. They would constitute the district coordinating institutions. Each district coordinating institution would have a desk officer for innovation. The coordinating institutions would organise to build the capacities of research and university staff to mainstream farmer innovation and participatory innovation development in the university curriculum.

Integrating into local government structures

Governance is decentralised to district, municipal and metropolitan assemblies headed by a local political head (a Chief Executive), who directs the implementation of the government and development policies, programmes and activities with funds allocated from the central government (District/Municipal/Metropolitan Common Fund) to achieve social, economic and infrastructural development at the local level, including communities. Projects and programmes are based on development plans designed by the assembly to address its peculiar development needs and challenges in infrastructure, agriculture, education, health, water and sanitation. With decentralisation, government's subsidised institutions, including MoFA, Forestry Department, Department of Cooperatives, Ministry of Women and Children, would access their budgets/funds from the District's allocation to implement their programmes and activities and would be accountable to the local authority. In the long term, PROLINNOVA–Ghana could take advantage of the decentralised local government system and structures and seek to integrate the LISF approach within identified relevant departments of the district, municipal or metropolitan assemblies to enhance development impact at the community level. It would lobby to establish an LISF within the local Assembly, where a percentage of the Assembly's common fund would be contribute to supporting farmer innovation and capacity building. In this sense, the Assembly would own the LISF fund, to which additional funds would be sourced from relevant development organisations. The MoFA, led by its local director together with the Assembly's planning officer, would be responsible for operating the LISF. However, because the allocation of central government funds to its departments, agencies and decentralised district and metropolitan assemblies is often inadequate and irregular, the likelihood of fund availability to adequately support LISF activities under this arrangement is currently uncertain, thus making this scenario the least feasible at this point in time.

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MORE PIECES WITHIN THE PIECES: RETHINKING THE FINANCIAL SYSTEMS FOR AGRICULTURAL INNOVATION IN BURKINA FASO

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Abstract

Financial services are considered as an essential tool for innovation diffusion. In Burkina Faso, the lack of appropriate financial services has been for long an obstacle for innovation diffusion in the agricultural sector. Until now, the few available financial services have been directed to mainly small scale farmers without regard to the emerging large scale farmers' group (agribusinesses). Thus, there is a need for rethinking these financial services in order for them to play a key role for both small and mostly large scale farmers whose contribution in the economy is important in Burkina Faso. Documentary review is the main data source combined with a qualitative analysis. It is argued that for better financial systems for agricultural innovation diffusion, there is a need to consider the production system.

Key words: financial services, Innovation, Agriculture, Burkina Faso

Background

Financial services are considered as an essential tool for innovation diffusion and is seen as a key pillar for Agriculture Innovation Systems. In Burkina Faso, the lack of appropriate financial services in agricultural innovation systems has been for long an obstacle for innovation diffusion in the agricultural sector. Until now, the few available financial services have been directed to mainly small scale farmers for agriculture intensification without regard to the emerging large scale farmers' group. Thus there is the need for rethinking these financial services in order for them to embrace the principle of inclusivity to play a key role for both small and large-scale farmers in Burkina Faso.

Problem statement

In the National Innovation Systems Framework for innovation diffusion, financial services are key component and play an essential role if the innovation system has to be sustainable. The question that arose is therefore how to make those financial services adapted and adaptable for better innovation diffusion for both small as well as large scale farmers in the country? It is argued that for the financial services to play a key role in innovation adoption in agricultural sector, there is a need to rethink the financial systems which includes large scale farmers. In Burkina Faso, small scale farmers who constitute the majority of the population, most of the time have little money in hand and thus have difficulties to access credit from financial services in order to invest on their farms / fields with the aim to increase agricultural productivity, and hereby facilitate access to agricultural innovation. Several financial services have already been implemented within the agricultural innovation system of the country. However there is limited information on the different types of credit schemes experimented on in the given farming systems of Burkina Faso. Documented lessons including the challenges, strengths and weaknesses in the financial knowledge generation and management may be used to guide both small and large scale farmers to participate meaningfully in the innovation diffusion processes.

Objectives

The main objective of this article is to investigate the extent to which the financial services can be proven strategies in support of all producers in the agricultural sector.Specific objectives include:

1. To make an inventory of financial services facilities experimented in Burkina Faso
2. To establish farmer type inclusivity in operations of financial services in the agricultural sector in relation to innovation diffusion.

Relevance of research

The financing of agricultural innovations is characterized by a diversity of financial services provided by the informal and formal financial sectors. These services are used primarily to finance agricultural inputs and equipment. The various studies on these products have focused on their effectiveness in terms of repayment rates, rising incomes and food security improvement. Even in cases where the diffusion of innovation was the main objective of the market of these services, the figures are very well provided in the literature to quantify this effect and more importantly show that up to now, small farmers are the concerned actors. This research is of practical and policy relevance and could contribute to the transformative integration of multi-stakeholder actors in the financial services systems in Burkina Faso in order to strengthen the links for sustainable agriculture innovation systems.

Literature review

The National Innovation Systems is a new conceptual framework which appeared during the 1980s in Science, Technology and Innovation Studies. It is considered as one of the first framework since the linear model of innovation and from the new policy framework to come (Edquist, 1999). To more clearly understand the National Innovation System (NIS) approach, it is necessary to look at the different steps it comes through with the parameters each evolutionary step involves.

In the current research, therefore, we are looking at the relevance of this approach for the analysis of Burkina Faso's financial system in the agricultural sector. From the beginning, the innovation model for science and technology development was linear. The NIS approach is hinged on the linear model and explained innovation as depending on scientific discoveries. Then, every innovation begins with these discoveries in Science (Dodgson, 2000), which are seen as the main actor in the development process (Manley, 2003). The first linear model considers that the high investment in R&D leads to productivity growth. This model includes: Basic science, R&D, production construction and marketing. All these elements are acting in a linear way (Manley, 2002). The first model called Science-Push Model was followed by another one (demand-pull) which includes: Demand, R&D, production construction and sales, named Demand-Pull Model (Manley, 2002). The interactive model or the 'chain linked model' (Manley, 2002) believe that the "Innovation is now understood as the result of interaction between various economic and social processes" (Manley, 2002, p.95). Therefore, different kinds of framework follow this model. Some considerable activities have been set in order to develop new approaches in understanding the current innovation processes. The different concepts used by Manley in the first interactive model have been redefined in the new system approach. Thus, innovation is seen in this respect as an interactive and complex process. Furthermore, some influential studies of system approach emerged. These nonlinear models of innovation extend upon the linear models by considering interactive and recursive terms into account (Etzkowit & Leydesdorff, 2000). They could change the causal relationship between the input and output. The authors considered the trilateral networks and the hybrid organisations as the keys to solving the economic crises. Indeed, this framework of the new system approach suggests that the research eventual target is innovation. At that time the new way of thinking and the use of the concept innovation are settled. It is defined asthat set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institution to create, store and transfer the knowledge, skills and artefacts, which define new technologies... (Metcalfe, 1997: 289) cited in (Carlsson, 2006: 58)

During the period 1990s and 2000s, the importance of the innovation system was widely approved and spread in developed and developing countries. Many studies about innovation deal with the linkages between the university and industry which relationship should be implemented for a thriving R&D development. The Triple Helix as an analytical model was developed (Etzkowit & Leydesdorff, 2000). For the authors "the Triple Helix denotes not only the relationship of the university, industry and government, but also internal transformation within each of these spheres." (Etzkowit & Leydesdorff, 2000: 118).

According to Rogers (2003: 5), "diffusion is a process in which an innovation is communicated through certain channels over time among the members of a social system". There are, therefore, four main elements in the process of diffusion: innovation, communication through certain channels, time, and social system. These aspects must be fully met in every successful diffusion. Nevertheless, sometime, the diffusion process fails depending on the context where it takes place. The concept innovation "is an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (Rogers, 2003:12). The government's role, through the different policies and programs from which it undertakes its economic and social development, is now based on the innovation system processes. In addition, the importance of knowledge in the process of innovation diffusion has become an object of significant attention. Therefore, knowledge has become the key driver (OECD, 1999) which can achieve and enhance a sustainable economic growth. This view nowadays seems widely believed and adopted. The NIS defined as a system approach for economic growth is adopted in almost all the developing countries. Indeed, "It is almost universally accepted that technological change and other kinds of innovations are the most important sources of productivity growth and increased material welfare- and that this has been so for centuries." (Edquist, 1997: 1)

The contemporary innovation focus on four approaches: systems, networks, value-chains and clusters (Manley, 2003). These frameworks have gained some consideration by the scholars and policymakers. In Manley's (2003: 4) view,

> innovation is seen as the result of a complex set of linkages between actors creating, applying and distributing various kind of knowledge. Innovation performance depends critically on the way these actors relate to each other as elements of a collective system of knowledge creation and use...

The main concern from the current perception of innovation is how people are interacting in the production and the useful knowledge diffusion. This approach is interpreted in diverse ways. Sharif (2006) asserts that from the past 20 years ago even today the NIS remains a subject of several interpretations, "making it function as a boundary object" (Sharif, 2006: 756).

The NIS framework to study the financial services in the agricultural innovation systems

The NIS framework is a complete analytical framework which can be used to study innovation network. It can help understand the role and the position of the financial systems in the agricultural innovation system in Burkina Faso. From this perspective, the innovation capacity of a country reflects its innovation system as derived from its firms' capabilities and networks, science system, supporting institutions, and other research bodies to the extent that they are the sources of the generation, diffusion and use of knowledge (OECD, 1999). Distinctively focusing on the level of the nation-state, the National Innovation System considers that the dynamics of these institutions are inter-related with the broader macro-economic and regulatory context (communication infrastructures, factor market conditions, product market conditions, education and training system) (OECD, 1999). The contributions of the individual institutions are not considered in isolation but "how they inter-act with each other as elements of a collective system of knowledge creation and use, and on their interplay with social institutions (e.g., values, norms, legal frameworks)" (Smith in OECD, 1999: 24). In this inter-action, the government has a key role through its policy options and regulations. In sum, Lundvall has identified three key variables which are government, universities (knowledge producers) and firms/industries/business actors, financial services (users of knowledge) (Lundvall, 1985; 1992; 2007). In fact, "Innovation and technology development are the result of a complex set of relationships among actors in the system, which includes enterprises, universities and government research institutes" (OECD, 1999: 7). As underlined by Goto, "The national innovation system essentially consists of three sectors: industry, universities, and the government, with each sector interacting with the others, while at the same time playing its own role" Goto (2000:104).

In the NIS framework, the financial services play a key role in the success of the innovation, specifically in development context. It is important to compare and evaluate the existing financial system in agricultural innovation in light with the National Innovation System framework as described. It will help understand their specific role within the systems and in particular in the context of Burkina Faso. Thus, it will help propose some solutions for a more inclusive and successful innovation system.

Materials and Methods

Sampling and design

Considering with Silverman that "our research problem defines the most appropriate method" (Silverman, 2005:6), I decided to use a qualitative approach to conduct my research. Indeed, the National Innovation Systems (NIS) conceptual framework has enabled me to unpack the network of organizations, individuals and institutions involved in the agricultural sector in Burkina Faso with more focus on the financial services as an actor on the system. The systemic documentary review on financial services in Burkina Faso, the date it was introduced in the agricultural sector, its definition and the actors it was intended to what are the outcomes of the different financial services which were covered. The main data source which helped investigate the subject in hand regarding the financial systems are from documents on financial services in agriculture sector in Burkina Faso.

Data collection methods

Qualitative and quantitative studies were conducted with a review on farmers from farmers' organizations of the country and a systematic review (articles, reviews, reports and books) on financial services, followed by a content analysis was conducted by taking into account the different financial services, the origin, and the relationship between the financial services and the characteristics of the farming systems. Then an evaluation of the kind of existing financial services in Burkina Faso. Its weakness and strength in making the agricultural innovation systems work.

Data analysis methods

The notes from the review of documents were first manually summarized and then electronically saved. Particular effort was made to gather details about the context of the production of every piece of document in order to be able to characterize their content and through cross checking to highlight what each document includes and what it omits in relation to farming systems and financial services. The collected data were analyzed drawing on established analytical strategy in Science and Technology Studies. Consistent with this strategy, data are broken down into discrete parts, closely examined, and compared for similarity and differences. Events, happenings, objects, and actions/interactions that are found to be conceptually similar in nature or related in meaning are grouped under more abstract concepts termed "categories" (Strauss and Corbin, 1998:102).

Results and discussions

Financial systems for innovation diffusion in the agriculture sector in Burkina Faso

As underlined, in Burkina Faso the farming system is composed of small, medium and large scale farmers. Most of the financial services for the agricultural sector are more based on the developmental approach mainly directed to the large number of small farmers representing the majority of the farmers: around 85% small farmers, 10% medium size farmers and only 5% large farmers. The different financial services have aim to support farmers in order to boost the agricultural sector in the cash crop economy. Different financial services have been implemented in Burkina Faso since the independence. Among them we have:

The State subsidies

These are subsidies that are given by the government in support to small scale-farmers who lack cash to buy inputs. These subsidies are sometimes associated with the trade credit which comes from traders or input suppliers in order to promote agricultural intensification. This allows small and medium size farmers who are the beneficiaries to buy their seeds, fertilizers, herbicides and insecticides. As can be seen, the state subsidies for agricultural development is based on supporting the 'poor farmers' as part of the national agricultural policies. This financial services in the framework of the agricultural intensification are working with farmers providing them either with cash (in kind) or alternatively provide farmers with inputs, mechanizations and technical support (FAD, 2004).

However, the State subsidies as financial services to support small farmers in the framework of the agricultural intensification has not really improved farmers' living conditions. In addition, these subsidies have been for long in the agricultural sector when there were no agribusiness actors in the agricultural innovation system in most African countries including Burkina Faso. Such a financial system has kept its traditional way of assisting small-scale farmers and thus has not integrated the emerging large farmers who are key component in need for financial support to boost the agricultural innovation system (Simphal, 2012).

An inventory credit system, or “warrantage”,
As underline by FAO, (2012), such financial services are consisting of a farmers' organization and or its members, to get a loan guaranteed by setting a non-perishable agricultural product likely to increase in value as the time goes by. The crops are kept between 6 to 8 months and is given back to farmers’ team and or individuals households. In this circumstances, financial services evaluate products and issue a receipt to the group or individual farmer indicating the quantity and quality of his products Garrido and Sanchez (2015). The value is evaluated and the products stored at the market price at the time of storage. The store is double padlocked and keys kept under both farmers and financial services supervision. The bank grants a credit to the OP amounting to 60-80% of the value of stocks (FAO, 2012). The inventory credit is then granted; the amount is distributed to members of the farmers’ organization according to the stock made by each. Farmers usually pay the store/warehouse management fees that can be rented or own by them. During the storage period, the financial and the concerned farmers carry out regular checks of the products. The agricultural credit for the purchase of inputs and equipment and other services are to some extent offered by financial institutions. Generally, these require physical collateral such as banks (Garrido and Sanchez, 2015; Lesafffre and Pesche, 2002). Such a credit is directed towards small as well as the limited number of the middle size farmers without regards to the very few large scale farmers who even are small in numberare very essential in the agricultural innovation system.

Joint credit/group lending
It aims at facilitating the adoption of agricultural inputs and equipment. It also offers the opportunity to a large number of small producers who do not have hardware warranty benefit credit with the group's commitment (FAO, 2012; FAO, 2016). This credit is for farmers’ organization to seek financing from an international funding agency according to the needs of these members by filing a financial bond. The experience in Burkina Faso was of interest to the neighbouring countries. The experienced of Burkina Faso was on cotton input credit and equipment. Indeed, the group organized producers’ benefit of the loan with the guarantee as surety and collection of reimbursements to marketing (Wampfler, 2004). Also known as a secured credit, it seems to be a good option to promote agricultural innovation. If successful, the social credit of cotton is largely based on the monopoly of cotton companies. Although effective, the social credit involves relatively high interest rates (over 10%). Thus, promoting widespread adoption of innovations with such credit requires political will and a strong involvement of not only development partners but more importantly large-scale farmers who are until now missing in the system. As in the State subsidies, joint credits are concerned with mainly small scale farmers and the loan is designed for all level of farmers. Thus, large farmers are not being paid much attention.

The guarantee fund projects and research and development programs.
The credits on the basis of guarantee funds for development projects and programs have also played a relevant role in the innovation deployment in case of agricultural inputs and equipment in Burkina Faso agricultural sector. Thus, the credits on the basis of guarantee funds for development projects and programs have played a relevant role in the innovation deployment in case of agricultural inputs and equipment. In Burkina Faso, as in other countries in West Africa, many projects have improved the level of innovation adoption of animal traction and inputs through these funds. But as in the case of other systems, most of this information remains in the project reports and thus unworkable in the context of this documentary review. In Burkina, the guarantee fund of many projects have allowed the farmers' organisations to access storage bags, inputs, etc. (FAO, 2012). The guarantee fund although very effective in terms of innovation deployment because all small farmers have access to credit, they do not seem to give significant results. These funds generate a culture of non-repayment of the loan in full, so in most cases the credit operation stops with the end of the project or program (Wampfler, 2004).

It suggests that various listed financial services explicitly or implicitly contribute to the promotion of agricultural innovations on-farm. The existing financials services are directed to small farmers and therefore facing challenges. Most of the financial services for the agricultural farmers are more based on the developmental approach mainly directed to the small farmers. The different financial services from this approach have aim to boost the agricultural sector in the cash crop economy. For instance, the state subsidies, the trade credit which comes from traders or input suppliers to promote agricultural intensification in that it allows the seed funding, fertilizers, herbicides and insecticides. An inventory credit system, or "warrantage", which allows farmers to stock part of their harvest in a warehouse for several months, and use the bags as collateral for a loan if they choose. The group lending aim for a secured credit, the intensifying initiative comes from farmers organisations. It appears as a true innovation deployment tool but the literature is very sparse on its potential contribution. The credits on the basis of guarantee funds for development projects and programs have also played a relevant role in the innovation deployment in case of agricultural inputs and equipment in Burkina Faso agricultural sector.

The sustainability of trade credit depends on the financed speculation and credit provider organization. Indeed, the credit seems to be effective in the cotton industry in Burkina Faso and this success is based on three main reasons: (i) the first is the marketing monopoly that cotton companies possess; (ii) the second is the fact that cotton is the only crop that has a safe and organized input credit which encourages producers in this culture even though credit conditions are not as profitable for them and (iii) the third is the surety that not only limits the credit management costs but also facilitates the repayment is not individual because this is the group that pays all loans of its members and not individual members. Roesch et al. (2004) summarizes the security of cotton credit to two main elements: the surety of all the members of a peasant organization and collection of loan repayments at source through the monopoly on collecting the harvest. The financing of agricultural innovations is characterized by a diversity of financial services provided by the informal and formal financial sector. These services are used primarily to finance agricultural inputs and equipment. The various studies on these products have focused on their effectiveness in terms of repayment rates, rising incomes and food security improvement. Even in cases where the diffusion of innovation was the main objective of the the market of these services, the figures are very well provided in the literature to quantify this effect. But, based on the theories of adoption and diffusion, importance can be given to these financial services to the extent that the choice of producers in terms of agricultural innovation is based on income. All financial service that improves the income would be instrumental in agricultural innovation appropriation. But although the literature is sparse in terms of evaluating the efficacy indicators in the agricultural innovation adoption, formal products including inventory credit, the collateral management system and group loans seem to be the most appropriate for microfinance and producers. The efficiency of financial services is a function of the required guarantee, the mode of granting, the grant amount and availability of time to credit and the credit object.

Small is big: Agricultural Production Systems

As can be seen, the farming system in Burkina Faso has evolved over time and has changed from domestic agriculture which purpose was exclusively for family consumption. Then, at some point there was a move to domestic and market agriculture which has open up to new aims including family consumption and trading on the local market. Finally, the market agriculture which goes beyond the local market to the international one.

Some ways Forwards: Putting the Pieces Together

In this synthesis, there are a variety of financial services that differ among sources of financing, the characteristics of the beneficiaries (small and large producers) and target cultures. The different financial services used more or less contribute to the appropriation of input and agricultural equipment. But their effectiveness in deploying sustainable agricultural innovation (adoption and reimbursement) would depend on the funding agency, types of producers, safeguards procedures, the credit-granting fashion (type or species) and extension system accompanying the distribution. The volume of loans adapted to the demand of small farmers and guarantees relatively appropriate to the context of production of the producers (the case of warehouse receipt and collateral management for example). In these systems there is close monitoring of credit and regular monitoring with seriousness to ensure refund.

The different existing financial systems in Burkina Faso are all based on developmental approach. Therefore, the conditions of commercial banks are not yet knowledge-based sensitive. Thus, we know that not all investments can be expected to be supported by private! Innovation financing system goes beyond direct loan systems- investment in infrastructure, human capital, basic research, incentive systems etc. There is a need to shift for a competitive approach: community to individual or mix depending on stakes.

The financing of agricultural innovations is characterized by a diversity of credit terms offered by the informal and formal financial sector. These services are used primarily to finance agricultural inputs and equipment. The various studies on these products have focused on their effectiveness in terms of repayment rates, rising incomes and food security improvement. Even in cases where the diffusion of innovation was the main objective of the marking to market of these services, the figures are very well provided in the literature to better quantify this. But, based on the theories of adoption and diffusion, importance can be given to these financial services to the extent that the choice of producers in terms of deployment of agricultural innovations is based on income. But the efficiency of financial services in the innovation deployment in Burkina Faso is limited in part by the low agricultural credit envelopes. It is therefore very important to adjust to the particularities of agricultural finance towards agribusiness instead of small-scale farmers in order to respond to the growing demand for a larger loan which require major institutional changes**.** In order to effectively respond to the demand for larger loans, a much higher level of expertise in agriculture finance is needed than what existed at the credit union level.

Conclusion

Like most African Countries, Burkina Faso has demonstrated that up to now, there is a lack of appropriate inclusive financial service for agricultural innovation systems in the country. Thus, innovation requires a more diverse financing systems that could address the diverse needs of heterogeneous actors in the innovation systems. As most of the African countries, Burkina Faso is currently integrating the idea of innovation. What is crucial is that African countries should work to depart from aid. Indeed, aid is for survival, innovation is for competition and emancipation. In the framework of the National Innovation Systems, financial services are key component which need to be integrative benefiting both small as well as very few large scale farmers.

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TRANS-BOUNDARY ORGANIZATIONS AND POLITICAL DIRECTION TO INNOVATIONS IN RESEARCH: THE CASE OF AU'S PROGRAMME ON TRADITIONAL MEDICINE AND PHARMACOPOEIA

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Abstract

Since 1974 the African Union has delegated research on traditional medicine and pharmacopoeia to the African and Malagasy Council for Higher Education (CAMES), in francophone Africa. It was expected that if scientists produced more and more knowledge on the topic it would result automatically in innovative health technologies that would help improve the health of the population. On further examination, it appears that the AU's approach has so far been based on the traditional linear model of innovation. With the development of interactive models, it raises the question of what have been the implications of this sustained linear approach in the type of research done by researchers taking part in the instituted biennial conference since 1974? Based on a systematic bibliometric study of the papers presented at the conference since 1974, this paper sets to contribute to answer this question, with the aim to draw scientists' attention on to the scope of their research and for policy-makers to rethink their interventions for a better health of African population. It argues that the organisational arrangement set by the AU resulted in a professional capture of the programme.

Introduction

Background

In 1968, the African Union, then the Organisation of African Unity (OAU), convened in Dakar, in Senegal, the first inter-African symposium on African traditional medicine and pharmacopoeia. This initiative is in fact the continuation of a late colonial nationalist project. Indeed, as part of the nationalist process, which was to lead to independences in the 1960s, African indigenous political elites decided to 'complement' the local unions with 'a big Gathering of all (these) organisations' during a meeting on the 11^{th} to 13th October 1946 in Bamako. A health commission was formed at the meeting, which had the aim to 'fight assimilation and defend "African originality"'. As part of its agenda, the Health Commission explicitly considered the rehabilitation of African traditional medicine by recommending "The creation in each territory of a laboratory and a school of herbalists for the utilisation of indigenous pharmacopoeia".

Called the 'great pan-African plenary', the post independent 1968's meeting renewed the continental recognition of its traditional medicine and endeavoured to seek its effective development. To this end, in francophone Africa, it has since appointed the African and Malagasy Council for Higher Education (CAMES) for the follow-up coordination and evolution of traditional pharmacopoeia and medicine in the member states of the region. The Council instituted an annual conference, held for the first time from 19th to 22nd November 1974 in Lomé, in Togo. The conference is still held biennially until today.

Problem Statement

This political option to only promote research by delegating the initiative to the scientific community alone, features a specific understanding of the role of the scientific profession and innovation process. Like any profession, the scientific profession was believed to be working only toward the public interest, while the quantitative increase of scientific production would result automatically to industrial innovation, and thus in health promotion of the population. Since the 1980s, new approaches in innovation studies have challenged this view (Godin, 2007).

From the beginning, the innovation model for science and technology development was linear. It was through "the linear model", also called "Science-Push Model" or "demand pull" according to which end when one stands, that process of economic growth is studied. This model, which lasted almost from the 1950s to the 1970s, explained innovation as depending on scientific discoveries. Then, every innovation begins with these discoveries in science (Dodgson, 2000), which are seen as the main actor in the development process (Manley, 2002). The first linear model considers that the high investment in R&D leads to productivity growth. It is followed by another linear Demand-Pull Model (Manley, 2002), which sees demand as driver of innovation. The African Union's approach to innovation in traditional medicine and pharmacopoeia is very similar to the science-push model.

Beginning in the 1980s, an interactive model became established in the 1990s in many OECD countries. From the early 2000 this model, particularly the National Innovation Systems framework has become increasing popular (Freeman, 1982; Lundvall, 1988). In this regard innovation is considered as an interactive, recursive and complex process. According to Metcalfe, the concept of National Innovation System "is a system of interconnected institution to create, store and transfer the knowledge, skills and artefacts, which define new technologies..." (Metcalfe, 1997, p.289). The key idea to the purpose of this paper is that without the appropriate interconnection, in which government and other actors have some indispensable role to play, research cannot result in innovation.

Objectives
The aim of this paper is to proceed from this case to underline the current need for a system approach to research and innovation, consisting of putting the efforts of various trans-boundary institutions and stakeholders together effectively, if research in traditional medicine and pharmacopeia is to result in new solutions for health promotion in Africa.

Relevance of research
Since 1974 the African and Malagasy Council for Higher Education (CAMES) has been organising biannually the conference in traditional medicine and pharmacopoeia, with the financial support of member states and development agencies with the expectation that the output of research would result in innovative medicine and medical technologies for the benefit of the population. The present research is both scientifically and politically relevant. It will draw academics attention as to the need to rethink the scope of their research. As to policy-makers it will provide them with more understanding of the productivity of their financial support toward the scientific community, as well as evidence for action. This is a fundamental sociological question.

Literature
This is however a challenging study when considering the available literature on science studies in Africa. Indeed, the earliest debate about science in Africa involved literary critiques for the rehabilitation of knowledge about Africa. Banning reports of the study of Plato on Egyptology and attempts to assign reasons from that and other literature, for the fall off from sustaining early civilization, statecraft, agronomy, scientific enquiry, the art of writing and architecture, followed by long grand migration into "impenetrable areas" that did not allow transfer of technical knowledge and skill. (Banning, 2000). Although, the time of mainstreaming has long arrived with significant improvement in infrastructure, sustained economic growth into middle class economies, more investments into education, research and regulatory laboratories, elevated consumer awareness of quality, the problem of raising modern scale industries from African indigenous literary and scientific knowledge remains a challenge as was first raised by African literary writers. The following statement, made by a famous English historian, in 1962, would best set the background for understanding the literary movement about African culture. The historian said: "perhaps in the future there will be some African history to teach. But at the present there is none; there is only the history of the Europeans in Africa. The rest is darkness…and darkness is not the subject of history" (Hugh Trevor-Roper quoted by Crowder, 1968:11).

In the colonial context, particularly its francophone part, this statement was the common discourse in the relationships between Blacks and Whites. The literary movement developed in reaction to such a humiliating discourse towards Black peoples around the world. Framed through the concept of *négritude,* a group of literary young Africans sought, from the 1930s, to revitalize Black cultures through literary work. The intellectual and political movement, which originated as early as 1935, with the journal *l'Étudiant noir* (1934-1935), was founded by Aimé Césaire, Léopold Sédar Senghor, Léon Gontran Damas, Guy Tirolien, Birago Diop et René Depestre, under the patronage of French intellectual elite, Jean-Paul Sartre and others (Senghor, 1992). The *l'Étudiant noir* was a forum for Black students who felt necessary to erect a thick wall against the wave of tribalism which was beginning to breakdown their unity. The concept of *négritude* served thus as platform which transcended African micro-identities to unite a young generation of intellectual caught up within the same humiliating web of French racism.

It is conveyed, on the one hand to reject the cultural assimilation carried out by France in her colonies, and on the other hand to express the Black civilisation in its own right (Césaire, 1956; Senghor, 1964). From 1947, Alioune Diop founded *Présence Africaine,* to take forward the ideas initiated in the *l'Étudiant noir.* As Diop has put it, regarding Alioune Diop, "an African through and through, he wanted to rehabilitate the collective memory of the peoples of Africa, and that memory is nothing other but their culture in its various aspects. To bring new life to the Africans from inside their culture was one of the primary goals of the founder of *Présence Africaine.* To disseminate and to make that culture a familiar one and to be recognized by the entire world was the second goal. Yet another was the place of the Black and their scientific philosophies being at *par* within humankind as well as their early recognition in the universal world-view" (Diop 1992: xiii). In other words, according to Mudimbe (1992:xvii), *Présence Africaine,* " wishes to bring in the very centre of the French power and culture what was being negated in colonies, that is, the dignity of otherness".

The intellectual movement succeeded to some extent but it opened up a window for anthropological thinking (Kuper, 2010) although later challenged by philosophers and historians (e.g. Diop, 2006). Following this literary literature, are philosophical reflections about knowledge production in and about Africa. Similarly to the early literary and political movements manifested through the *négritude,* early philosophical discourse focused on two main interrelated dimensions. Firstly, philosophy continued the quest for recognition of Black African culture, as set by the literary critiques. As such, a cultural rehabilitation was not only the precondition of the existence (material and symbolic) of African peoples, but also the very condition of possibility of science in general. African societies were to be first recognized as historical societies, in order to be worthy of scientific discourse. Secondly, apart from this "socio-historical origins" of discourses, their production depends on "epistemological contexts" (Mudimbe, 1988: ix). It is [these epistemological contexts] which make them possible and which can also account for them in an essential way" (Mudimbe, 1988:ix).

Amongst the outstanding philosophers who addressed this challenging question, is Cheikh Anta Diop. He went further than the promoters of *négritude*, by supporting theses about the universality of human civilisation, without losing sight of what constitutes the peculiarity of African civilisations, as the motherland of human civilisation (Diop, 1962). Besides, with regards to Western authors' negation of the possibility to use African languages for scientific practice, Cheikh Anta Diop provided evidence of "possibilities of expression of wolof in particular and African languages of culture in general" (Diop 1975: 154). In other words, more than an effort of vulgarisation, he studied this case as "the concrete demonstration of the possibility of scientific discourse in African language" (ibid: 155), giving thus means for rooting science in Africa. Later, as this identity enterprise was relatively established worldwide, the crucial issue for Diop was how to develop a pan-African science which would constitute the foundation for African development. Indeed, as early as in 1974, during a debate about a "new model of science policy in West Africa", he concluded that "research is therefore the source for renewal of the world in the most general and deep sense. It provides new techniques for the field of everyday practice. It increase man's hold on nature and makes him the active agent of transformation of the world" (Diop 1974:85). As a result of this, in contrast to what was then mistakenly held, Diop saw research and higher education interdependent (Diop, 1974:85), and urged "Africa … to opt for an intellectual and scientific development policy and take responsibility for the sacrifice this requires" (Diop, 1974:87). Diop foresaw current scientific and technological subordination denounced by African scholars, and which Hountondji (1992) is particularly concerned with. The common characteristic of this literature is its experimental character; it aimed at demonstration, not at theoretical development about how to study science.

Even the recent social science literature on science can be challenged in this respect. The evidence suggests however that even there, the interest has remained at the level of theoretical commentaries than thorough empirical research. The social sciences have approached the problem in terms of the development of an autonomous African science, with more focus on the social sciences. Indeed, there is a long standing engagement of African scholarship with African social sciences for the promotion of an alternative discourse about African societies (e.g.Fyfe, 1976; Zeleza, 2006). However, recent evidence suggests that persisting structural and institutional factors still make the development of an indigenous social science a major challenge, particularly for West African social scientists (Sall and Ouédraogo, 2009). Structurally, in this region, the increase of programmes and enrolment in social sciences is a recent trend. Indeed, before the end of the 1960s universities could only be found in very few countries: Ghana, Nigeria and Sierra Leone.

In French West Africa, the earliest universities were created at the beginning of the 1960s (1959 for Dakar, 1963 for Abidjan and 1970 Benin; Ouagadougou 1974). The significant increase in the number of higher education institutions occurred in the 1990s and 2000s, under a strain economic context which started from the 1980s. Institutionally, the 'epistemic rupture' that Adesina (2006) proposes in order to bring an indigenous social science about, that would contribute to global scientific debate, is constrained to remain a mere idea for a certain period; because the mechanisms of institutional reproduction set by colonialism continue to operate through training of academics staff and various cooperation schemes. As Sall and Ouédraogo have underlined with regard to Sociology, "[a]lthough autonomous research and higher education institutions have now been established in most independent African countries, the foundations for strong academic cultures and theoretical propositions are yet to be established in many of them. The economic adjustments of the eighties and nineties came too quickly to restrict the development of the institutions and frustrate the hopes for progress of the science of sociology." (Sall and Ouédraogo, 2009:7). On the whole, West African social scientists, as those of the rest of Africa, seem to be experiencing a marginalizing condition in a global world, despite their paradoxical significant role in the reproduction of that global knowledge.

Nevertheless, some optimistic views have been emerging in recent years which propose that a re-engineering of African Journals' publishing policy would improve the visibility of science in Africa, by making it available in the global knowledge domain (Nwagwu, 2008). In the absence of these emerging channels for dissemination, West African scholars have long relied on 'chances' for publishing in print international journals, with more pressure to do so in these recent years by 'university administrations and managements' (Omobowale, 2010:3). This quest for international publishing has become common behaviour among African scholars (e.g. Nwagwu, 2006; Nwagwu and Egbon, 2011). These studies have two main weaknesses. First, they are meta-analysis and prospective reflections. Second, they emphasize the dimension of circulation of knowledge than the content of that knowledge. Also they do not consider the organizational implications on content and structure of scientific productions. This literature takes further the traditional debate about the colonial roots of knowledge produced about African societies and its consequences on African development. This literature emerged first among African first intellectual and political elites (e.g Mudimbe, 1992; N'Krumah, 1974; Nyerere, 1967). Then it became dominated by philosophical controversies, latter complemented by historical contributions (e.g. Diop, 1974; Fyfe, 1976; Jewsiewicki and Mudimbe, 1993; Ki-Zerbo, 1973; Mudimbe, 1988; Zeleza, 2006). Social science of sciences in Africa remains a continuation of this social philosophy, without engaging in fieldwork research (Ajayi, 1973; Sall and Ouédraogo, 2009). A very few scholars has taken this empirical direction (Omobowale, 2010). Nevertheless, at least this literature provides a theoretical attempt of understanding science. This aspect is particularly present within the small but rich empirical research from largely European scholars.

This research developed a grounded literature from strong engagement of the classics in the science studies in order to understand scientific and technological institutions in developing countries such as those of Africa (Arvanitis et al., 2000; Gaillard et al., 2013; Gault, 2010; Mouton, 2008). However, the fact that most of this literature result from development agencies-sponsored research made it very limited to address more complex processes in research and innovation in the continent, particularly its francophone part which is the subject of this study. Moreover, new Partnerships across South-South, North-South, Government-Private or Public Sector Partnerships are making in-roads in making trans-boundary organizations bring excellence in science education and research and accelerate transfer of knowledge into improved products and services by attracting other intermediate and commercial developers who are capable of overcoming regulatory and market bottlenecks to bring about the impacts of economic scale and health benefits of significant permanence.

Conceptual Framework for Policy Direction to Research

From the 1990s new ways of studying science policy developed, drawing on a political economic theory called Principal-Agent Theory. The theory originates from information economics on incomplete information and risk sharing in the domain of insurance (Moe, 1984). Basically, "The principal-agent model is an analytic expression of the agency relationship, in which one party, the principal, considers entering into a contractual agreement with another, the agent, in the expectation that the agent will subsequently choose actions that produce outcomes desired by the principal"(Moe, 1984:756). In science policy, it received currency through its development in the new approaches in economics of organizations (Moe, 1984). Its relevance for science policy studies is revealed by Braun (1993). Studying science funding policy, Braun (1993) observed that, "The relationship between policy-makers and scientists becomes therefore a relationship of delegation" (Braun, 1993:310), meaning that like in market relations or in bureaucratic hierarchies, science policy-makers face similar issues of Principal-Agent regarding responsiveness, adverse selection, moral hazard and priority-setting. This resulted in a variety of organizational arrangements (contracts, collaborative research works, networks) depending on the extent of policy-makers' implication, in the expectation to reconcile the requirement of scientific autonomy and political accountability.

Guston (1996) later elaborated the application of this model in science policy by generalizing the assimilation between Principal-Agent model and the structure of science policy. He then refined the concept because its political economic origins tended to lead to considerable clarification of responsibilities of the respective position of principal and agent to make collaboration, cost and effects work efficiently. Drawing on the sociological literature on science, Guston argued that the boundaries between science and politics is not an essence, but constructive, and social processes are working to legitimize the traditional delegation as the modern arrangement allowing participation of relevant actors through the setting up of a network of trans-boundary organizations institutions and stakeholders of interest in innovations from traditional knowledge (Guston, 1996; 2001; 2003). Within the same framework, significant contributions have been made to advance our understanding on countries' experiences in science-government relationships (Callon et al., 1995; Meulen 1998; Mustar et Wright 2010) as well as how research organizations' internal characteristics shape their approaches to coordination (Wardenaar and al., 2014).

This is particularly relevant for understanding the role of research in traditional medicine and pharmacopoeia in innovation in health systems in francophone Africa, because, there, the structure of science policy tend to follow the traditional model of innovation with the result of delegating research to scientists with active participation of other stakeholders in order to shape effectively the innovation system. Understanding this principal-agent relations will significantly advance our understanding as well as policy interventions to the study of science and innovations in Africa. There is little on such study for the moment in the existing literature.

Methodology

Combining literature survey and institutional analyses, this sociological proposal on organisational design for innovation policy is structured into three sections.

Sampling design

This paper is based on a systematic study of conference reports produced since 1974.

Data Collection methods

Bibliometric study: It will draw from the methodology developed by Chaletin and Waast (1997) to study the structure of the contributions in traditional medicine and pharmacopoeia as provided by the conference reports. The first step will consist of a *rapid assessment* . This is done by the counting of all publications from the database affiliated to the country. The unit of analysis is the publication which is described by the country, institution, and laboratory of the authors. Then secondly, each publication unit is described according to its object, methods, and aim. These two processes will enable to aggregate the publications by domain (area), which in turn is categorised by items and sub-items, leading to a reconstruction of the structure of the publication in the area.

Data analysis methods

The data will be analyse trough descriptive statistics. Tables will be created on key variables.

Results and Discussion

213 participants authored the 114 papers published from the five editions, here reviewed, of the African and Malagasy Council for Higher Education's Conference on African Traditional Medicine and Pharmacopoeia. Of these 213 participants only 2 have a social science background (Table 1). As the table shows, 99.06% have a background in the natural sciences. These include pharmacy, botanic, chemistry, physiology, medicine and nursing.

Table 1: Distribution of authors of papers from conference proceedings by discipline

Disciplines	Total	%
Natural Sciences	211	99.06
Social Sciences	2	0.94
Total	213	100

The most striking result of this analysis, shown in Table 2, is that the 211 participants with natural science background came up to 3.8% participants having a medical background. Seven have medical degrees whereas 1 has nursing degree. As shown in Table 3, medical sciences and social sciences are poorly represented in the 5 editions considered for this preliminary analysis.

Table 2: Distribution of authors of paper from conference proceedings within the Natural Sciences discipline

Disciplines	Total	%
Natural Sciences	211	100
Medical Sciences (medicine, nursing)	8	3.8
Others	203	96.2

Disciplines	Total	%
Social Sciences	2	100
Anthropology	2	100
Others	0	0

This under representation of medical sciences is supported by evidence from the analysis of the research themes covered during the five editions. As can be seen in Table 4, there is no specific theme related to medical sciences. Among the natural science related papers, papers on clinical and pharmacological research picked at 33.3% followed by physico-chemical research (23.7%) and then botanical and ethnobotanical research (15.8%). The paradox arises from the high representation of papers on organisational problems despite the fact that only 2 participants with social science background is recorded for the five reviewed editions of the conference, and who only contributed with one paper each for the whole five editions. This implies that the majority of the contributions related to the organisation problems are made by participants with a background in natural science.

Table 3: Distribution of authors of papers from conference proceedings within the Social Sciences discipline.

Themes	Total	%
Botanical and Ethnobotanical Research	18	15.8
Clinical and Pharmacological Research	38	33.3
Physico-Chemical Research	27	23.7
Organizational Problems	31	27.2
Total	114	100

Although there has been a downward trend for contributions in all the themes, the fall in contributions on the organisational problems had been particularly sharp. While they outpaced any of the topics in the natural sciences, with seven and twelve papers, respectively in the first and second edition, the number of contributions started falling down afterwards with only 2 in 1994. The trend is quite the reverse for the other topics, because whereas the number of contributions was small during the first and second editions, it improved during the third edition with 12 papers each in clinical and pharmacological research as well as in physico-chemical research. A similar relative improvement is observed in botanical and ethnobotanical research, with six papers in 1979. However, overall contributions on organisational problems and physico-chemical research sharply reduced around the 1990s, contrary to contributions in botanical and ethnobotanical research (4 papers in 1994) as well as in clinical and pharmacological research (7 papers in 1994).

Table 4: Distribution of papers from proceedings by themes

Themes	1974	1976	1979	1988	1994	Total
Botanical and Ethnobotanical Research	5	1	6	2	4	18
Clinical and Pharmacological Research	3	7	12	9	7	38
Physico-Chemical Research	1	4	12	8	2	27
Organizational Problems	7	12	6	4	2	31
Total	16	24	36	23	15	114

These trends in the contributions according to disciplines and topics of research are not random. They are structured.

Conclusion with policy recommendations

It was argued that the organisational arrangement set by the AU would result in professional capture *of a network of experts, stakeholders and multi-centre information on traditional medicine and pharmacopoeia*. The analyses demonstrate that this professional capture is achieved by natural scientists in general and pharmacists in particular. This reflects processes within single countries. There is an urgent need for the Council to reform the organisational structure associated with the mission it delegated to CAMES, if innovation and discovery have to result from the research missions to accelerate Africa's contribution as a net producer of health products, solutions and health technologies, even if it is one major discovery at a time. Attracting governments into innovation development, harnessing inspiration and technology of the champions in innovations development in both the south and the north to overcome the regulatory and market bottlenecks, delivering on a meaningful scale aimed at impacts of mutual benefit and improving global health that is attractive to the Private sector and having an intermediate Management, Monitoring and Evaluation Agency that set targets, remains an outstanding challenge. (Excerpts from the Annual Meeting of Grand Challenges for Global Health, 24th October, 2016)

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IMPLEMENTATION OF GHANA'S NATIONALLY DETERMINED CONTRIBUTIONS (NDCS) TO THE UNITED NATION FRAMEWORK ON CLIMATE CHANGE – THE ROLE OF EBAFOSA GHANA

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Abstract

The Ecosystem Based Adaptation for Food Security Assembly (EBAFOSA) is a Pan African Organization whose target for policy and ground actions to facilitate sustainable ecosystem based adaptation (EBA) agro-industrialization powered by clean energy is directly in consonance with Ghana's NDC goals. EBAFOSA mandate in Ghana is tailored to include enabling Ghana operationalize its NDCs. Specifically, target sectors of Ghana's NDCs that can be aligned to EBAFOSA roles and functions include; agro-forestry and reforestation to enhance Ghana's forest sinks and enhance ecosystems and adaptation capacity, clean energy expansion where clean energy powered agro-industry minimizes sources and sustainable land use in agriculture. Furthermore, equitable social development through effective agro-industrialization linkages would create jobs and income opportunities along the entire agro-value chain. In achieving these milestones, the role of EBAFOSA- Ghana can become very essential.

Introduction

Ecosystem Based Adaptation for Food Security in Africa (EBAFOSA) is the first ever inclusive pan-African framework and platform, an institution with protocols, a constitution and rules of procedures adopted in an inclusive continental process, guiding its actions that provide a platform for all stakeholders in a country. It includes governments and their agencies, the public and private sectors. Other EBAFOSA stakeholders include educational and research institutions, individual publics and citizens. Others include CBOs, international inter-governmental organizations, NGOs, CSOs etc who collaborate in participatory ways to develop and implement policy solutions.

The broad goal is to upscale ecosystem based adaptation driven agriculture and its value chains toward ensuring sustainable inclusive growth in Africa (EBAFOSA Website). Collaboration is the mutual engagement of participants in a coordinated effort to solve a problem together. Collaborative interactions therefore are characterized by a high degree of negotiation, interactivity and interdependence.

EBAFOSA seeks to combat food insecurity, climate change, ecosystems degradation and poverty in Africa using an innovative approach that decentralizes the development and application of the policy solutions in the least bureaucratic channel to ensure immediate results are recorded at the grassroots in an inclusive, participatory way towards achieving the sustainable development goals (SDGs).

EBAFOSA attempts to provide optimized solutions to implement existing and envisaged workable development plans for the African continent. EBAFOSA's principal mandate is to support the implementation of the various continental and global blue-prints on food security and sustainable industrialization and development.

These blue-prints includes the SDGs, The AU's Agenda 2063, the AMCEN Cairo Declaration on Natural Capital, Maputo and Malabo Declarations and related CAADP which recognizes EBA-driven agriculture as priority mechanism for delivering the CAADP vision 2025, with objectives such as ending hunger in the continent by 2025, reducing post – harvest losses by 50% and leveraging agriculture and Africa's natural capital to achieve sustainable industrialization and inclusive economic growth.

According to reports from myjoy.online.com, Ghana needs $22.6 billion in investments from domestic and international public and private sources to finance its climate mitigation and adaptation actions. Ghana's Intended Nationally Determined Contributions (INDC) was submitted in September, 2015 to the United Nations Framework Convention on Climate Change (UNFCCC) in France. The INDC is the Ghanaian government's proposed contribution to the UNFCCC in terms of what it will do about climate change (Cole, 2008; Farber, 2007)

Review of Literature

Ghana's INDC encompassed thirty-one programme of actions to derive the strategic focus of a ten year post 2020 enhanced climate change action plan that was to be developed after the COP21 of the UNFCCC in Paris in December 2015.

Ghana's INDC is hinged on five facets; its medium-term development agenda (The Ghana Shared Growth Development Agenda II – GSGDA 2); the National Climate Change Policy, the Low Carbon Development Strategy, the anticipated 40-year long-term development plan and the Universal

Sustainable Development Goals. The proposed measures to achieve Ghana's INDC goals will build on existing measures and strategies (GH-INDC, 2015). In total, 11 adaptation and 20 mitigation programme of actions covering seven priority economic sectors have been proposed for implementation in the ten-year period spanning 2020-2030.

The implementation of the actions are expected to help attain low carbon climate resilience through effective adaptation and greenhouse gas (GHG) emission reduction (Galbreath, 2011; Ludi et al., 2012) in the priority sectors of sustainable land use including food security, climate proof infrastructure, equitable social development, sustainable mass transportation, sustainable energy security, sustainable forest management and alternative urban waste management. In the achievement of these seven milestones, the role played by EBAFOSA-Ghana cannot be ignored.

Most of the Ghanaian population are migrating from the rural areas due to lack of job opportunities, since Agricultural productivity is dwindling and much of the food they produce is wasted due to a lack of markets for their produce and inadequate knowledge of effective food preservation techniques. In addition to the changing climatic conditions, land degradation and high competition on land for mining and construction is the low demand for local farm produce, driven by negative perceptions of locally-grown food and the sophisticated demands from the growing middle class.

Planning for implementation of Ghana's Nationally Determined Contributions (Gh-NDCs)

In the planning for implementation of the Gh-NDCs, EBAFOSA's role is made manifest by the building blocks for NDC implementation (Benefor, 2016). In the building block 2 of the building blocks for Ghana's NDC implementation, institution strengthening and engagements are highlighted with specific activities for strengthening and coordination, stakeholder engagements, awareness creation and communication. Other building blocks where the role of EBAFOSA will be critical are Building blocks 1, 3, 4 and 5. Among strengths of EBAFOSA to be become essential force in the implementation of the Gh-NDC, are the strengths in peer learning and the capability to exchange innovative approaches among members.

EBAFOSA's structure is premised on recruiting focal persons who volunteer in the implementation of the building blocks of the Gh-NDC. With the kind of decentralized structure that EBAFOSA has, it will be much realistic for those sub-national focal persons to develop action plans to support the implementation of the Gh-NDC.

In learning from this example, all EBAFOSA operations, activities and roles will be decentralized into the respective regions and sectors following the same model of regional and sectoral focal persons.

Methodology

EBAFOSA Strategic Layout

The Ecosystem Based Adaptation for Food Security Assembly (EBAFOSA) forms part of a global movement and membership of the EBAFOSA Africa which is under the United Nations Environment Programme (UNEP). EBAFOSA's key strength as actualizing partnerships among solutions providers, which indeed is an innovative imperative to ensure the implementation of opulence international plans, especially the Seventeen (17) Sustainable Development Goals (SDGs) and post COP21 Actions.

Considering sustainable development as an overriding theme, EBAFOSA focuses on building relevant partnerships across solutions providers in public and private sectors, local and international, and on leveraging healthy ecosystems as central to achieving food security, sustainable industrialization and inclusive growth. This positions EBAFOSA as a platform that could potentially see Africa achieve meaningfully all the SDGs and particularly SDGs 2 – Zero Hunger, 8 – Good Jobs and Economic growth, 13 – Protecting the Planet, 15 – Life on Land and 17 – Partnerships for the Goals. Hence, the need for the involvement of all Stakeholders, policy makers and non-policy makers and a linkup of policy makers to EBAFOSA, academic and research institutions as a strategic layout to boost and achieve the targets for which EBAFOSA was set up.

The activities to be undertaken at the strategic policy level, will focus on connecting key non-policy actors along the value chain to policy makers and also facilitating inter-policy maker's interactions; while the operational level, actualize connections among non-policy actors.

The strategic level aim is to target and engage policy makers in the Ministries of Agriculture, Finance, Environment, Trade and key Ministries Departments and Agencies (MDA) towards up scaling Ecosystem Based Adaptation (EBA) and its value chains and link them with the other stakeholders. This will be tackled on 3 levels;

1. *Link policy makers to policy makers*: this is to ensure efficient policy implementation, breaking the silos between policy makers in different ministries, departments and agencies. For example, deeper collaboration between the ministries of Agriculture and Environment will ensure EBA driven agriculture techniques becomes part of mainstream agriculture approaches. While the Ministry of Trade will ensure appropriate policies needed to facilitate the private sector for commercialization and value addition enterprises along the value chain are put in place, the Ministry of Finance also ensures appropriate budget allocations for the programmes put in by the Agriculture, Environment, and Trade Ministries.

2. *Link policy makers to on-going on-farm EBA initiatives and value addition enterprises*: This will ensure that *on-going on-farm* actors can engage and dialogue with policy makers to actualize the formulation and implementation of favorable policies to enhance out-scaling, horizontal up scaling and more areas under EBA techniques and value chain commercialization.
3. *Link policy makers with Academia and Research Institutions and other International bodies:* This will enable further enrichment of policies and policy making e.g. through adoption of latest research findings to inform policies and adoption of most effective, optimal approaches to policy making.

EBAFOSA-Ghana will create a collaborative platform for policy makers to interact with EBAFOSA and among themselves as well, indicating that EBAFOSA targets not only policy makers but citizens, including farmers and all actors in the agriculture value chains.

The transfer of information and knowledge from policy makers would be suitable and beneficial to the stakeholders and farmers. The value chain and value addition services which includes guiding farmers to add value to their produce to maximise profit.

At the operational level, EBAFOSA seeks connections and linkages among non-policy actors in order to facilitate peer learning, access to markets, access to technologies, linking products to accreditation and certification services to help access more lucrative local and export markets. This practically means:

- Linking registered farmers to registered value added service providers with the appropriate innovations, knowledge, skills and technology e.g. innovative storage technologies, innovative preservation technologies; alternative energy grayers and processors, efficient irrigation technologies, innovative mobile based supply and demand market access technologies.
- Linking registered farmers to registered processing markets e.g. fruit processing industries, animal feeds industries, flour processing industry, brewing industry, flower packaging industries and others.
- Linking both on farmer producers and other value added products to institutional accreditation and product certification services in order to create worth for their produce.
- Linking registered farmers to registered extension and training service providers *on* EBA technologies and other value chain technologies e.g. supporting farmers to sort, grade and package produce before taking it to the market.
- linking registered farmers to registered markets for fresh produce: this targets individual consumers end users like agro-processors i.e. individual members of EBAFOSA, corporate and institutional consumers and businesses, resellers including Petty Traders, Supermarkets, Kiosks, Shops and other Retailers as well as Wholesalers, who may be under the EBAFOSA platform and beyond.

Results and Discussion

Targeted outcomes

Members of EBAFOSA Ghana, are profiled, categorized or clustered along key focal areas and themes reflected around the targeted outcomes of the Assembly and also take advantage of the huge internal capacity for service provision to the members.

EBAFOSA Ghana could become more attractive if educative platforms are facilitated through the mobilization of regional members including the media for seminars to create awareness on the assembly, inform and educate consumers on status of agricultural and food products on the national market, sensitise farmers on best agronomical practices, the need to strengthen farmer-based associations and form cooperatives in efforts to commercialise their agricultural business.

EBAFOSA's role in empowerment of farmers towards commercialization of agriculture and the green economy, could help farmers participate effectively in the crop value chains, control their product pricing and increase their profitability, which will go a long way to boost the local economy of Ghana.

Discussion - EBAFOSA benefits

The last 30 years have been phenomenal in human history and there is no doubt that Africa is set to converge, however, this is not pre-ordained, and do not depend on the declarations of good intent, but the willingness to operationalize what works for the collective benefit and prosperity of all African people (Richard Munang, UNEP Kenya)

Benefits to Governments

EBAFOSA as the vehicle to be used to domesticate relevant continental and global development blue prints on leveraging ecosystems for food security, will promote inclusive growth and sustainable industrial development so benefits accrue at country level;
It is an engine of- job creation for youth through leveraging global, continental and country level supply and demand side agro-value chains;
It is an engine of investments through - facilitating partnership and networking leading to Public Private Partnerships (PPPs) and other mutual interactions with the private sector for economic development.

- An engine for job creation for youth through leveraging value chains
- Leveraging country level supply & demand side agro value chains
- Leveraging ecosystems for food security, inclusive growth and sustainable industrial development
- A means to emission reduction and green economy

Benefits to NGOs, CBOs and other CSOs

EBAFOSA provides a platform through which CSOs (NGOs, CBOs) mandate can be delivered at a broader scale, hence benefit more people. It also facilitates continental peer learning in techniques, approaches and best practices for country NGOs from counterparts across the African continent. Technical capacity building can also be fostered for local NGOs through interactions with diverse stakeholders and especially research institutions, and the private sector. Helping CSOs

- to work with and empower local farmers and promote local food production for poverty alleviation
- to help empower rural smallholder farmers via training and access to markets
- facilitate the buying of crops from smallholders farmers, processing the products and packaging them for the target market
- provides a viable way for rural smallholder farmers to market their indigenous crops and produce to meet both local and export market demands.

Benefits to Educational and research institutions

EBAFOSA provides a platform where Educational and Research Institutions in Africa can build mutual partnerships in research, dissemination of innovations, scholarship and academic exchanges between themselves and also across sectors with private sector, international organizations, governments, and NGOs in and across countries.
In addition, it provides an opportunity for education and research institutions to better inform country policies, as EBAFOSA works closely with and supports governments in policy up scaling and implementation.

Benefits to Students, Youth and Individual citizens

EBAFOSA helps to mobilize all players to address issues facing the youth in-country in terms of job creation through agriculture and agro-based value addition industry and enterprises. EBAFOSA membership is extended to the youth, students and individual citizens who are solutions providers and future leaders, ensuring that they get exposed to opportunities for technical capacity building e.g. through internships, opportunities to foster incubation of entrepreneurial ideas as well as employment opportunities.

Benefits to Private Sector.

EBAFOSA provides a continental platform for business to business, business to consumer networking and partnership, business to government partnership, business to educational and research institution partnerships along areas of mutual interest, especially, food security, climate change adaptation, job creation and employment. Thus contributing to improvement in business techniques, for instance through businesses benefiting from latest research on most effective business approaches from academic corridors, and also, directly fostering broad interactions, to growth in clientele, markets, influence and ultimately revenues.

EBAFOSA also ensures business brands are not only promoted at country, but continental and global levels, hence, facilitates the creation of more income opportunities for the private sector through;

- Continental platform to link business to educational & research institutions
- Linking business to government partnership along areas of mutual interest e.g. food security
- Linking business to business for interactions on mutual benefits and partnerships
- Linking business to consumer networking and partnerships

Policy Recommendations

Secured partnerships

EBAFOSA as a solutions space would bridge the gaps in policy implementation that have long stifled real substantial progress in Africa through fostering mutually beneficial partnerships between solutions providers to solve Africa's challenges. This provides a platform for interactions between stakeholders in Government, Private sector, Regional & Global Intergovernmental bodies, Academia & Research, NGOs, CSOs, CBOs, and Individual publics. By facilitating the growth of value-adding enterprises along the agro-value chain, EBAFOSA support Farmers capitalize on the demands of the growing middleclass in Africa for more diverse and processed foods, as a market for growth of African food processing industries.

This is indeed a huge potential, considering that the middle class has expanded to an estimated 300 million people and their consumer spending is projected to reach USD$ 1.4 trillion by 2020, hence, EBAFOSAs support for policy advocacy to promote consumption of local produce (e.g., Made in Ghana, Batakari Friday and others) will combat current imports (which cost Africa as high as USD 35 billion annually) and ensure these monies are ploughed back to the local economy.

There are motivating factors for EBAFOSA, strategizing partnerships with and among policy makers, food producers and private sector to ensure local produce is locally processed, value-added and marketed to this significant targets. This may create desired jobs through the value addition services, hence, the need to shun working individually but rather working as a team to grow our local economies.

EBAFOSA will provide a platform for these and others to interact with peers and leaders to further expand their enterprises all toward the common aim of building a prosperous, climate resilient food security for Africa.

EBAFOSA to upscale success stories

EBAFOSA is also used as a platform to promote and upscale Best practices and Successful Initiatives and Interventions. Building on the many but isolated successes that are ongoing across the continent, EBAFOSA will ensure success stories on the food security, job creation, employment and livelihood security potential of the agro-value chain, that have so far been only in pockets can be up-scaled to be the norm for the entire continent.

By working with women smallholder farmers to teach post-harvest techniques, food processing, marketing skills and nutrition. The blazing trail of women entrepreneurship by leveraging value addition through primary and secondary processing, marketing and offering training to local farmers. Thereby improving local agro-products value chains and creating more rural economic opportunities by linking farmers to markets and equipping them with the necessary skills to succeed. EBAFOSA is poised to feed Ghana and Africa, create jobs and employment opportunities, sustain local economies and ultimately eradicate poverty in a more sustainable manner.

Conclusions

Ghana's response to the problems imposed by the impacts of climate change has been to employ a coordinated domestic policy actions that in effect aims to develop a policy framework that integrates adaptation, mitigation and other climate related policies within broader development policies and planning. This is in order to achieve developmental outcomes from the impacts of climate change and build a climate resilient economy. EBAFOSA, with its strength and capabilities, is positioned to optimize climate resilient food systems, cross-ministerial policies requiring interventions from ministries of environment, agriculture, energy, infrastructure, and finance and planning, industry and commerce to enable the establishment of rural sustainable agro-industry simultaneously meeting both climate and socio-economic progress objectives. Connections focusing on linking non-policy actors to each other will facilitate peer learning, access to markets and technologies, access to finance, linking products to accreditation services and other linkages of value will help empower both men and women to upscale ecosystem based adaptation actions that may significantly contribute to Ghana's attainment of her Nationally determined contributions toward resilience to climate change and its impacts.

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Table 1

Ebafosa Ghana's Action Plan to Support Ghana's Nationally Determined Contributions (GH-NDC)

Ghana's NDCs priorities aligned to EBAFOSA	**EBAFOSA-Ghana's roles and strategy**	**EBAFOSA Initiatives**	**Time frame**	**Expected results – Articles of Paris agreement satisfied**
		MITIGATION		
Sustainable Energy Security -Decentralized renewable energy	**1.** EBAFOSA target for policy and ground actions to establish EBA-Based agro-industrial zones powered by clean energy, with decentralized systems being the most economically viable in rural areas convenes relevant stakeholder partnerships to actualize **2.** Comprehensive database of policy level and operational actors from private sector, academia and	EBAFOSA will support the national double energy efficiency improvement strategy and work with other stakeholders and interest groups to implement the National Energy Policy. EBAFOSA will work to support the sustainable energy plan	October 2016 – December 2018	Direct electricity cost saving Reduction in electricity demand Savings of $300 avoided power factor surcharge Phase out ozone depleting substances

	development partners engaged in decentralized clean energy systems			
Gh-NDC Policy actions **Integrated Solid Waste Management based on reduce, reuse and recycle principle**	**Ghana's emission reduction goal is to unconditionally lower its GHG emissions by 15% relative to a business-as-usual (BAU) scenario emission of 73.95 MtCO2e2 by 2030** **Modern biomass and the resulting useful forms of bioenergy produced from it are**	**Phase 1** **1.** Mapping out relevant planned & ongoing individual and institutional initiatives in country at both policy level and ground actions by government, private sector, academia, NGOs, development partners critical to implementing the INDC priorities **2.** Reach out, mobilize and register into EBAFOSA database the mapped out stakeholders / initiatives 3. Scale up renewable energy penetration education and awareness creation 4. Provide training and awareness creation to promote clean rural households lighting 5. Advocate for the expansion and adoption of market-based cleaner cooking solutions 6. Advocate for sustainable mass transportation 7. Advocate, train and educate the Ghanaian masses to promote sustainable utilization of forest resources through the adoption of the REDD+ principles Rapid increases in volume and types of waste agricultural biomass, as a result of intensive agriculture in the wake of population growth and improved living standards has become a big problem as rotten waste agricultural biomass emits methane and leachate and open	September 2016 –MARCH 2017 November 2016 – June 2017	We expect energy efficiency improvement to 5%

ADAPTATION **Sustainable Land Use and Food Security** *Agro-forestry and reforestation* *Agriculture* -Improved crop systems (upscale use of drought resistant crops; adopt better soil management practices) -Improved resource management (efficient agriculture water use; re-greening; better soil management)	**anticipated by many advocates to provide significant contribution to the global energy supply of many countries.** **ADAPTATION**	burning by farmers to clear the lands generate CO2 and other local pollutants. EBAFOSA – Ghana would act by raising awareness and building the capacity of local stakeholders to cover all the waste streams and all the stages of waste management chain such as source segregation, collection and transportation, treatment, material and energy recovery and final disposal. EBAFOSA will gather comprehensive data on present and anticipated waste situations, supportive policy frameworks, knowledge and capacity to develop plans and systems, proper use of environmentally sound technologies and appropriate financial instruments to support its implementation EBAFOSA will assess and link stakeholder markets for the bioenergy carriers produced as heat, electricity, gaseous fuels, liquid biofuels or solid biofuels **ADAPTATION** 1. EBAFOSA will create awareness, advocate and build capacities for agriculture resilience initiatives 2. EBAFOSA will create awareness, advocate and build capacities in value addition-based utilization of land and forest resources 3. Advocate and support efforts for a. city-wide resilient infrastructure planning b. recognition of early warning signs and disaster prevention	**ADAPTATION October 2016 – December 2017**	**ADAPTATION** We expect the yield of positive synergies with the mitigation support initiatives Awareness creation to reach some 10-15 Million

	A comprehensive database of actors from govt. policy level to operational level actors in academia, private sector, extension services etc., to foment mutual partnerships to integrate Ecosystems Based Adaption approaches (EBA) including up-scaled use of drought resistant indigenous crop varieties and other conservation approaches like efficient irrigation into mainstream agriculture policy and practice. Target will be proven techniques that increase yields while simultaneously restoring degraded areas, improving ground water recharge. A comprehensive database of private sector, academia, extension services to enhance dissemination & usage of efficient irrigation technologies in EBAs hence inform EBA integration into relevant policies in Ghana	readiness/preparedness c. Create awareness about climate-induced health risk and build capacities of sections of the Ghanaian population about the management of climate-induced health risk d. Build capacities in integrated water resources management a. Building capacities and promoting resilience initiatives through awareness creation for gender and the vulnerable in Ghanaian societies b. Promote outreach by informing, communicating and educating the citizenry and committing to accountable monitoring and reporting c. Create awareness, build capacities and promote innovations in post-harvest storage of food and processing of food – including grains, fruits, vegetables and roots and tubers	**October 2016 – December 2018**	Ghanaians Some 1000 people from Ghana to benefit from capacity building initiatives. Obtain adequate financing from both domestic sources and international sources Working with other agencies, help community based conservation agriculture to be adopted in 43 administrative districts Scale up penetration of climate smart technologies to increase livestock and fisheries productivity to the intended 10% by Gh-NDC Innovations implemented in post-harvest storage and processing in food and forest products
Forestry -Support review &	**1.** A comprehensive	EBAFOSA – Ghana would support	October 2016 – December 2018	Reduce deforestation

implementation of National Forest Policy -Forest restoration -Strengthen implementation of National Community-Based Forest Resources Management Programme	database of policy level and ground actors from both agriculture and forestry to foment mutual partnerships to Integrate Ecosystems Based Adaption approaches (EBA) that link agriculture to forestry into mainstream agriculture & forestry plans & policies and upscale ongoing ground initiatives. Simultaneous objectives are enhancing forest cover while improving food security. 2. EBAFOSA-Ghana EBA farm linked to additional stakeholders in government, academia, private sector etc., to upscale EBA practices and demonstrate restoration & conservation viability of EBAs hence inform EBA integration into relevant forestry, agriculture & other land use policies	enhancement of forest carbon stocks through the proposed 5,000 ha per annum enrichment planting and enforcement of timber felling standards through public and mass education, awareness creation and physically held tree planting exercises EBAFOSA – Ghana working to support National forest and wildlife policy, the Timber resource utilization regulation and the National REDD+ strategy		and degradation Reduce emissions of short-lived climate pollutants
Sustainable Mass Transportation	EBAFOSA convenes cross-cutting stakeholders for mutual partnerships to actualize policies & plans to enhance	Mass education and roll out of awareness creation on the use of mass transportation for efficient energy use and emission reduction	October 2016-December 2018	Work with other stakeholders to achieve increase in number of trips by public transportation by 10%

	investment in rural transport infrastructure – rural roads, to enhance efficient linkage of high potential agro-areas & agro-industrial zones to affluent urban markets & export centers. Target is to: **a.** Ensure shortest distance linking production zones to markets to minimize travel distances & related emissions **b.** Good roads ensure vehicles consume fuel efficiently hence lowers emissions.			

Climate Proof Infrastructure Linkages - Link actors from diverse fronts and support the active implementation of the national biodiversity preservation and strategic actions that address climate change impacts - Link actors and support recommended climate change adaptation policies and programmes in sectors that affect biodiversity conservation, including agriculture, forestry, energy and livelihoods. - Link various actors along the agricultural value chain. Build capacities, create awareness and support implementation of programmes for alternative livelihoods in order to reduce unsustainable resource use that contributes to loss of biodiversity	A comprehensive database of multiple stakeholders at both policy and operational level from bio-diversity dependent sectors / ministries i.e. environment, agriculture, forestry, energy, lands to ensure formulation, refinement and implementation of relevant sectorial bio-diversity conservation policy, plans and practices.	EBAFOSA- Ghana will facilitate EBA linkages to stakeholders in government, academia, private sector etc., to upscale biodiversity conserving EBA practices and demonstrate their viability hence inform EBA integration into relevant policies in forestry, agriculture, lands, energy & other biodiversity dependent sectors	October 2016 – December 2018	Community led adaptation and livelihood diversification for vulnerable groups Effective management of nearly 500,000 Ha fragile, ecologically sensitive and culturally significant sites in the assigned 22 administrative districts in the forest and savannah areas Governance reformed for utilization of forest resources for sustainable energy use and biodiversity business
Equitable social development EBAFOSA – GHANA will review and advocate for land use plans in industrial areas in light of equitable social development and climate change adaptation	EBAFOSA will educate the masses about favorable land-use practices to establish suitable locations for setting up rural agro-industrial zones powered by clean energy and build relevant stakeholder	**1.** ICT through mobile apps that enhance market linkages (instead of paper processes & physical travelling) create income opportunities for mobile innovators while contributing to climate resilience through minimizing sources **2.** Clean energy powered agro-industry	October 2016 – December 2018	Achieve emission reduction Enhancement of forest carbon reduction Reduce national poverty levels Reduction in electricity demands and expenditure

	partnerships EBAFOSA will partner the responsible agencies to set up EBA-Based agro-industrial zones powered by clean energy and ICT	creates income opportunities for processing industries while contributing to climate resilience through minimizing sources		
Livelihoods - Build a network of intermediate NGOs capable of working on climate change and livelihoods issues, where these NGOs support a number of communities in high risk States. -Animate communities with appropriate engagement methods, in order to elicit and document valid climate change and livelihood related needs/vulnerabilities -Use or reinforce available (endogenous) community resources to reduce vulnerability and build livelihood-linked capacity to adapt to climate change.	A comprehensive database of climate change and livelihood improvement NGOs and CBOs within Ghana and across partnerships and networks between them to facilitate peer learning cross-hybridization and exchange of innovative climate resilient approaches especially on enhancing food security	EBAFOSA-Ghana EBA farm linked to additional stakeholders in government, academia, private sector etc., to upscale biodiversity conserving EBA practices and demonstrate their viability hence inform EBA integration into relevant policies in forestry, agriculture, lands, energy & other biodiversity dependent sectors - Initiative on waste to wealth for electrification (Clean Energy) & Bio fertilizer	October 2016 – December 2018	Job creation for the unemployed and youth especially Improved urban sanitation and waste management Improved agricultural yield through the availability of organic fertilizer
Industry	1. EBAFOSA will create awareness and promote adoption of green technology in industry 2. EBAFOSA will build relevant stakeholder partnerships targeting policy and ground actions to establish EBA-Based agro-	1.EBAFOSA will upscale programmes on EBA approaches to food security **2.** Private sector companies will be partnered given them opportunities to enhance their corporate brand locally and nationally through engaging their Corporate Social Responsibility to support Ghana to implement Paris agreement & support	October 2016 – December 2018	**1.** Clean energy powered agro-processing & value addition to reduce operating costs and improve profits **2.** Digital marketing systems will reduce paper processes related emissions **3.** EBA technologies to

	industrial zones powered by clean energy and ICT enabled market linkages / digital market systems enhancing adoption of clean technologies in industry as follows:	national socio-economic development priorities **3.** Financial institutions will be engaged to establish EBA based agriculture climate risk sharing facilities to lower the cost of agriculture finance risk and simultaneously finance climate adaptation given EBA is a climate adaptation technique 4. Initiative an waste to wealth for electrification (Clean Energy) & Bio fertilizer		ensure agro-industrialization will enhance forest sinks. 4. Sustainable yield increases will improve farmer level incomes while contributing to climate adaptation given that EBA is an adaptation technique

PART 2: THE NEXUS OF INNOVATION AND ENTREPRENEURSHIP

INSTITUTIONAL ENTREPRENEURSHIP FOR INNOVATIONS IN AGRICULTURAL VALUE CHAINS: WHAT MORE FOR PROJECT-BASED PARTNERSHIPS?

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Abstract

Creating innovations in agricultural value chains is increasingly being pursued by diverse actors (private companies, governments, donors and NGOs) within the context of project initiated partnerships. Using an inductive research approach, this paper outlines the processes different types of project-based partnerships (PBPs) undertake towards innovations, and the outcomes of the processes on export- and food value chains. Drawing on empirical research in Ghana, the paper has highlighted the key activities of a team of institutional entrepreneurs at three different stages of institutional entrepreneurship. Institutional entrepreneurship is the activities of actors who have interest in particular institutional arrangements, and therefore leverage support and resources, to create or transform such institutions. The paper shows that institutional entrepreneurial activities lead to the introduction of new institutional arrangements (e.g. new ways of organising smallholders) in value chains. We however argue that PBPs cannot create innovations in value chains to their full expectation, because it entails dynamic responsive practices, through which the introduced institutional arrangements are enacted. Thus, PBPs should understand these adaptive practices and engage in strategic institutional entrepreneurship, that could lead to preferred innovations in agricultural value chains.

Key words: value chains, partnerships, agricultural development, institutions, innovation platform

1. Introduction

The creation or change of institutional innovations requires a multi-actor collaborative effort (Pant, 2012; Hounkonnou et al., 2012). Agricultural projects therefore increasingly comprise of collaborations between diverse actors (donors, public actors, NGOs and private actors) as a "means of developing strategic direction and coordination" (Brinkerhoff, 2002: 21), to establish efficient and inclusive value chains (Gregoratti, 2011). These collaborations have been described as public-private partnerships, innovation platforms, or communities of practice. While differing in approach, they share similarities in that, they all want to create collective action for transformations. This paper focuses on project-based partnerships (PBPs), which are multi-actor configurations deliberately set up with donor support and an agricultural development agenda (Devaux et al., 2009). These PBPs, also engage field-level actors to implement specific interventions on their behalf.

In most literature on PBPs for institutional innovation in value chains there is little detail about the processes, and how actors engage in them (Henson, 2011). Institutional innovations are new practices, norms, and rules organizing the relationships between different actors in a system (Hargrave and Van de Ven, 2006). PBPs may formulate institutional arrangements (e.g. input delivery services, joint experimentation and learning), to enhance access to input- and output markets, credit and food production (Poulton et al., 2010; Vellema et al., 2013). The paper aims at providing in-depth analyses of how actors are involved in institutional innovation processes, to contribute to knowledge on how PBPs create innovations in value chains. The concept of institutional entrepreneurs is applied to enable us focus on actors who have interest in particular institutional arrangements and leverage support and resources, to create new institutions (rules, norms and practices) or transform existing ones (DiMaggio, 1988). In addition, we use the concept of institutional bricolage which is the "creative piecing together of different arrangements, styles of thinking and sanctioned social relationships to produce new or adapted institutions" (Cleaver, 2001:16).

In the next section we present the conceptual framework, followed by the methodology used. Then data from two different case studies are presented, to analyse the unfolding innovation processes. Finally, empirical findings from the cases are discussed, and the paper concludes with practical implications for using PBPs as strategy for institutional innovations in agricultural value chains.

2. Conceptualising Institutional Innovation

This section integrates insights from value chains and what conditions they provide that could cause institutional entrepreneurs to emerge, and the activities they then engage in towards achieving particular goals.

2.1: Value chain conditions as triggers for institutional entrepreneurs to emerge

Value chains comprise an entire system of production, processing and marketing, from inception to finished product. The literature on IE (Battilana et al., 2009) argues that imperfections or opportunities in such 'organisational fields' create tensions or gaps, which are conditions for the emergence of institutional entrepreneurs. The initiation of PBPs are often based on value chain imperfections or shortcomings that challenge the legitimacy of existing rules or practices and trigger the creation of alternative institutional arrangements.

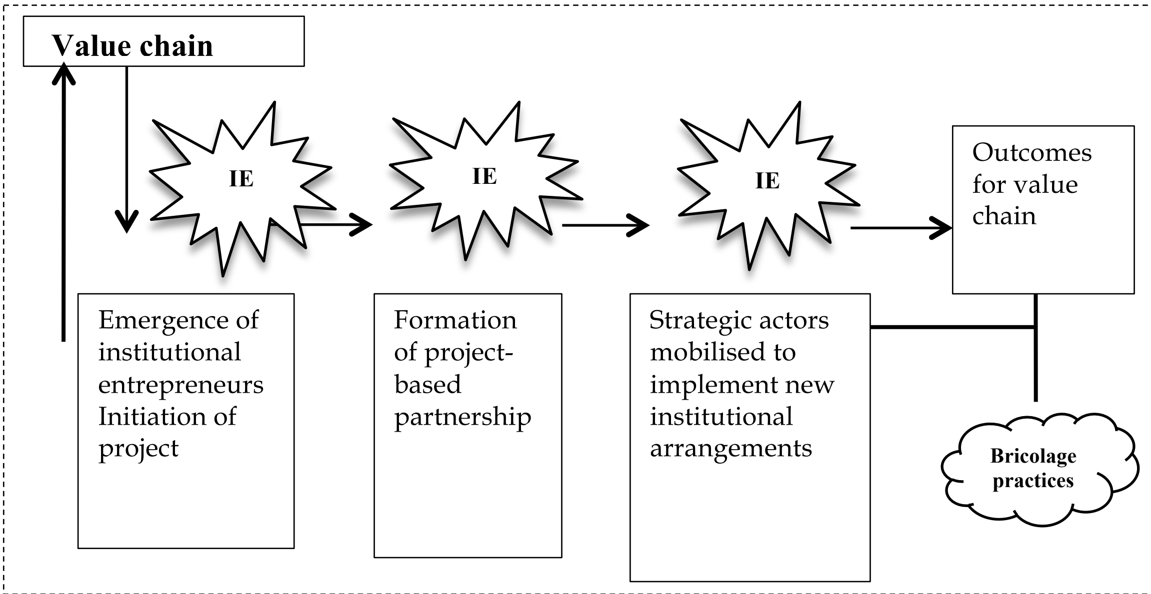
2.2 Institutional entrepreneurship: the activities of institutional entrepreneurs

Institutional Entrepreneurs (IEs) can arise from the private-sector that seeks to promote their economic interests (Greenwood and Suddaby, 2006), through the transformation of value chains they operate in. IEs may also come from the public sector ministries, donors, research institutes or NGOs, who have legitimacy and critical resources to initiate institutional innovation. In most cases, institutional entrepreneurs are able to create networks for value chain development, because they are connected to different realms (e.g. trading, processing, production) and issues e.g. product quality, profit distribution (Klerkx and Aarts, 2013). Their main activities are developing and mobilising support for a vision of innovation (Battilana et al., 2009). To articulate a vision, they reflect on the imperfections in value chains, make sense of them, and create a communicative strategy to share with relevant actors (van Paassen et al., 2014). Institutional entrepreneurship (IE) leads to the formulation of new institutional arrangements that are expected to address specific shortcomings in the value chains. These may however result in unexpected outcomes due to institutional bricolage (Cleaver, 2002).

2.3 Institutional bricolage

Institutional bricolage underscores the messy nature of implementing new institutional arrangements (Cleaver, 2001). It involves adaptive processes through which actors modify proposed institutional arrangements, invent new ones or reject them to fit it to their institutional logics, which guides "how the actors make sense of and act upon reality" (Fuenfschilling and Truffer, 2014:774). Three main bricolage practices (De Koning, 2011) have been conceptualised as: *Aggregation*- the practice of accepting new institutional arrangements. *Articulation*- the practice of rejecting new institutional arrangements to maintain local identities or routines in passive or active ways. *Alteration*- the practice of modifying the new and/or existing institutional arrangements to make them fit specific needs.

In summary, Figure 1, presents an analytical framework which visualises the field as a value chain, the conditions that allow institutional entrepreneurs to emerge are explored, then IE is analysed. At the same time, how different field-level implementers enact new institutional arrangements introduced from IE are looked at. The bricolage practices help us to understand the ‘modifications’ of new institutional arrangements promoted by IE of PBPs, which then shows how the outcomes could create enabling conditions in the value chains for further IE.



3.1 Selection of cases

Two PBPs were purposively selected based on the types of partnership and value chain. Both are donor funded, project-based initiatives set up to transform value chains within a wider context of achieving specific development goals (e.g food security, sustainable production systems and improved smallholder livelihoods). The PBPs are categorised as public-private partnership (PPP) and innovation platform (IP). The PPP involves formal contractual agreements whilst the IP is set up as an informal arrangement between diverse actors. One case focuses on cocoa value chain, which is mainly coordinated and regulated by the Ghana Cocoa Board (COCOBOD). This value chain is important for the national government as a source of rural livelihood and export earnings. The other is on food crop value chain, which is locally organised as an important source of revenue and food for the rural/urban population, and mainly coordinated by local and informal relationships. The cases studied are: *Cocoa Rehabilitation and Intensification Programme (CORIP)*; and Ghana’s cassava project under the *Dissemination of New Agricultural Technologies in Africa (DONATA).*

3.2 Methods

The research design followed an inductive strategy (Eisenhardt and Graebner, 2007), and in-depth qualitative (Yin, 2009) approach to provide descriptions of institutional innovation processes. Project documents from the cases were reviewed to identify actors, their roles and at what level of a partnership they operated. Using purposeful sampling techniques, in-depth face-to-face interviews were conducted. Interviewees included donors, programme managers, local NGO managers, and value chain actors.

Data were collected between the period of January 2015 and August 2016. Information was initially gathered through document analysis of project annual review reports, organisational reports and action plans. Primary qualitative data was collected using interview guides, all interviews were tape recorded and fully transcribed. Initial findings of the research were presented at two different knowledge sharing workshops for validation by diverse actors (e.g. project focal persons, actors from private and public organisations, value chain actors, and researchers). The data were analysed through a systematic procedure of coding, transcribed data were categorised and key elements compared with concepts of IE and IB practices as outlined in the conceptual framework.

4. THE INSTITUTIONAL INNOVATION PROCESSES OF PBPs

4.1 Institutional entrepreneurship in project-based partnerships

This section is a detailed analysis of IE in the PBPs studied. We first present the value chain conditions that led to emergence of institutional entrepreneurs and then focus on activities they engage in.

The main cocoa value chain context that triggered the emergence of institutional entrepreneurs in the case of *CORIP* was, inefficiencies in the supply of agro-inputs (e.g. fertilisers, seedlings, pesticides) to cocoa farmers. This triggered actors to emerge and take action in a PPP to address the institutional constraint.

For the food value chain, *DONATA* realised that cassava can enhanced famers' income and national food security, yet, cassava farmers had limited knowledge on different options of high-yielding cassava varieties, market information, inefficient production and processing practices and a lack of coordination between the value chain actors. Actors were thus mobilised around innovation platforms (IPs) to strengthen the innovation capacity (knowledge exchange and action taking) for institutional innovation.

Institutional Entrepreneurship of PBPs

We describe in the boxes below the IE of the PBPs, and then analyse trends that emerge from the cases. Three main different stages of IE were identified as: *1st stage*- initiation of a project, *2nd stage*- formation of PBPs and *3rd stage*- implementation of institutional arrangements by field-level implementers. We found that each stage is directly linked to a preceding one.

For *CORIP*, the institutional entrepreneurs identified were: a senior level officer from an embassy (donor), a programme manager appointed by an international NGO, as the focal person, and a consortium (group of senior actors from donor, national and international public organisations, and cocoa private companies); sets of licensed buying companies (LBCs) and counterpart private cocoa company (field-level implementers).

1st Stage of IE

*Donor searches for opportunity to support development in cocoa sector
*Donor commissioned and funded consultant and cocoa mission to assess gaps in cocoa value chain
*Donor formulated a programme around identified gap of inefficient supply of agro-inputs *Donor framed vision of '*effective supply of agro-inputs*' in a draft programme steering note
*Donor mobilised funding, and communicated vision to an international NGO by using discourse on '*cocoa sector productivity and sustainability*'
*International NGO appoints a focal person and programme is initiated

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2nd Stage of IE

*Focal person made sense of vision by interpreting it as a '*cause of untimely supply of inappropriate agro-inputs, leading to low productivity, which will be solved by the effective supply of appropriate agro-inputs to farmers*'
* Focal person through motivational framing communicated the vision to relevant actors in his network
*Focal person facilitated series of meetings between senior level actors and mobilised actors from cocoa companies; COCOBOD, international public organisation interested in agro-inputs systems, and another donor to join and collaborate in a partnership. MOUs were signed, consortium and programme advisory group (PAG) formed
*Focal person with inputs from consortium prepared governance and programme implementation manuals, and formally formed a committee of technical experts
*Focal person facilitated meetings with consortium, PAG and technical committee, and the vision was re-interpreted and formulated into institutional arrangements for creation of rural service centres, that was outlined in a call for proposal template
*Focal person called for submission of proposals from cocoa companies and counterpart LBCs.
*Focal person mobilised funds and disbursed to successful applicants to implement the new institutional arrangements in the cocoa value chain

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3rd Stage of IE

*Focal person facilitated meetings and field visits of consortium and programme advisory group
*Cocoa companies and LBCs mobilised local actors, facilities and funding for the implementation of introduced institutional arrangements
* Focal person engaged in monitoring and evaluation of implementation process

In the case of *DONATA*, we found the institutional entrepreneurs to be: senior officer of an African research organisation; West African research and development organisation; a scientist (focal person) from a Research Institute in Ghana; Director of a district agriculture development unit (field-level implementer).

1^{st} Stage of IE

*An African agricultural research organisation through the assessment of its initiatives found many proven varieties and technologies by scientists are not effectively disseminated for adoption by farmers
*A senior actor of the organisation at a Heads of African governments meeting shared the challenge under the discourse of food security through technology adoption
*The actor interacted with an agricultural development bank representative present at the meeting, on the need for funding to set up a project for '*effective dissemination of technologies that will increase farmers productivity*'
*The research organisation communicated to the West African research and development organisation, a vision of supporting national agricultural research systems in Africa to disseminate their technologies to farmers within a frame of innovation platforms. The organisation was formally invited to collaborate, a consortium of the representatives of the bank and the two research organisations was formed and the project initiated
*The research organisations facilitated a meeting of stakeholders at which the vision was framed as '*low farmer productivity due to lack of linkage between scientists and farmer*'
*The organisations, in Ghana formally invited the Council for Scientific and Industrial Research to partner the project and coordinate its activities.
* The Council appointed a focal person, MOUs were signed and

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2^{nd} Stage of IE

*Focal person made sense of the project concept document by prognostically interpreting the vision as '*low yields in cassava production due to lack of access to high yielding varieties and lack of coordination between value chain actors*'
*Focal person informally communicated the interpreted vision to a director of district agricultural development unit to get buy-in for the project to be implemented in his district
*Focal person organised a regional level stakeholders' workshop, at which she used the discourse of multi-stakeholder engagements to explain the need for innovation platform arrangements to enhance interactions between scientists, extensionist, and value chain actors (farmers, processors, input dealers, transporters and traders). To ensure effective experiential learning, access to input and output markets
*Focal person organised district level workshop for extensionist and value chain actors and introduced the project as one that will create an innovation platform and also link actors to scientists and extensionist for joint learning
*Focal person mobilised funding from the project, and signed agreement with the district unit for implementation

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3^{rd} Stage of IE

*Director of district agricultural development unit with inputs from focal person networked to communicate vision to actors of a local NGO and FM station for their support in the implementation process
*Director invited and facilitated a meeting of potential innovation platform leaders, and informally tasked them to mobilise interested value chain members for setting up innovation platforms in their communities

This case study showed that, senior actors from donor and international public organisations took the lead in the 1^{st} stage of IE, envisioning and initiating the PPP projects for inclusive development. The PPP vision did not focus on a situated learning and development process like in the innovation platform, but to sign agreements with key actors for large-scale value chain transformation. In the 2^{nd} stage, the PPP used diagnostic and prognostic framing to mobilise consortium or advisory board partners, who were knowledgeable in the domain and could help to operationalise the vision, articulating the Terms of References of the envisaged new institutional arrangements. *CORIP* involved government actors to ensure the partnership aligned with national development frameworks and regulations. The *CORIP* focal person used prognostic and motivational framing and a 50% financial support to incite private actors to establish Rural Service Centres (RSCs). To address the shortcoming of agro-input supply through RSCs, aligned with the private sector interest in '*an ensured sustainable, highly productive cocoa resource supply*' (Box 1).

Insights from the IP *(DONATA)*

In the IP case study, a researcher was identified as the 1st stage IE, who took the initiative to define imperfections in value chains, leverage resources from a donor and formed a project. Studies revealing the limited impact of linear, technology driven research and development approaches, made agricultural researchers recognise the need for demand-driven multi-stakeholder approaches. The 1st stage IEs identified researchers at national agricultural research institutes as focal person, to test the IP approach. In the *DONATA* case, the focal person's task was to use the IP approach to create agricultural development with the technologies available. She mobilised IP partners with the prognostic vision of an IP approach, coupled with the promise of project funding. She primarily mobilised colleagues at the District Agricultural Development Unit (DADU), responsible for planning and extension. It was the director of DADU that became the IE of the 3rd stage: with funding, he was able to mobilise local IP leaders and their community, as well as the local NGO support needed for the implementation (Box 2). Along the process, IP members realised local development processes are highly influenced by the institutional context, especially market relations and policy support. The participation of private companies however, could not be sustained, because they were not motivated as the platform was more interested in research and learning which did not directly benefit their companies.

Comparing export and food value chains

In the cocoa export value chain, *CORIP* aimed to improve the efficiency and smallholder inclusiveness of ongoing rules and routines. For the food value chain however, *DONATA* had to start at the local level to establish new technological practices, relationships and routines between farmers, processors and markets. Government coordination and support existed on paper but there were not enough interest or resources to implement the tasks. The IP opportunity, vision and funding however easily attracted committed local government officers to network and support local development initiatives. As private companies are mainly based in urban areas, the food value chain, mainly worked with local NGOs, district agricultural development unit and IP executives to enhance agricultural production, improve processing activities and linking up with local market small-scale traders.

4.2 What more for PBPs? - Institutional Bricolage

In this section, we analyse the institutional bricolage processes: how actors actually enacted the institutional arrangements promoted by the IEs. A tabulated summary is also provided with an overview of the enacted institutional arrangements and bricolage.

4.2.1 Institutional Bricolage in *CORIP*'s PPP

Institutional arrangements for collaborative action

The envisaged collaborative arrangement for action by *CORIP* comprised:

- The creation of a consortium (donor, cocoa private companies, international NGO) and advisory body (government officers, donors, private cocoa companies, international public organisation and NGO), to operationalise vision into concrete call for proposals, criteria for eligibility, contracts stipulating what the institutional change that the contract partner should realise.
- Setting up of technical committee to assess the project proposals and actual field situation of potential contract candidates on the criteria for eligibility, and to assess the monitoring reports of the PPP contract execution.

The consortium, advisory body and technical committee were formally established as envisaged by the 1st stage IEs, and together they articulated the eligibility criteria, rules for project implementation, monitoring and evaluation of the PPP contracts. This part of the collaborative arrangement was highly formalised; there was little or no bricolage; and the collaboration was seen as temporary as it was supposed to end as soon as the project and contracts expired. However, the format of 'consortium agreements, advisory bodies and PPP contracts' become a popular tool to create new value chain engagements and development impact on a large scale, hence in a way the first stage IEs have introduced or reinforced the institutional arrangement of PPP projects.

Institutional arrangement at value chain level

Through the PPP contracts, *CORIP* incited private actors to invest in the training and service provision for the farmers, who produce the resource base (cocoa) of their business. They promoted the establishment of RSCs, but the different private companies enacted this idea differently. They bricolaged the idea, to make it better fit their company's institutional logics (refer to Table 1).

Table 1: Summary of institutional arrangements at the value chain level

	Institutional arrangement at value chain level				
	Existing institutional arrangement	**Promoted new institutional arrangement**	**Enacted institutional change**	**Bricolage practices during project**	**What will plausibly remain after project?**
CORIP (PPP)	Buying of cocoa beans; implementing certification, rehabilitation and intensification projects with access to input component	Establishment and operation of rural service centres for distribution of agro-inputs	Different institutional arrangements of agro-input supply services through: * Establishing and operating of rural service centres * Distributing inputs through lead farmers in communities by the use of farmers' request list * Providing inputs services through mobile vans *Using acquired agro-inputs directly on farmers' fields	Aggregation (2 accepted new arrangements) Articulation (5 rejected new arrangements)	A more private sector-led alternatives of providing agro- inputs to cocoa farmers

Source: Authors' compilation

In the *CORIP* case, the LBCs were used to buying cocoa beans from farmers under a commission-based incentive agreement with COCOBOD. They also, in collaboration with cocoa companies, implement certification, climate change and farm rehabilitation projects with organised farmer groups (Table 1).

The call for proposal with clear formal rules and signed agreements on 'what and how it has to be done' imposed the new institutional arrangement on the field-level implementers, who implemented the rules differently than expected. This is because the arrangements did not fit into their existing institutional logics of buying cocoa and/or rehabilitating cocoa farms. In response to these developments, the *CORIP* programme initiators acknowledged they cannot completely orchestrate change in agro-inputs delivery to cocoa farmers against interests of field-level implementers.

4.2.2. Institutional Bricolage in IP (DONATA)

In the case of *DONATA*, the district agriculture development unit, as existing practice was involved with coordinating agricultural activities, providing advisory and technology transfer services to individual farmers. The new institutional arrangement was: '*creating innovation platforms for joint identification of cassava value chain constraints for joint action'*.

Table 2: Summary of institutional arrangements for collaborative action

	Institutional change for collaborative action				
	Existing institutional arrangement	**Promoted new institutional arrangement**	**Enacted institutional change**	**Bricolage practices during project**	**What will remain after project?**
DONATA (IP)	Independently coordinating agricultural activities of the district, providing general extension services to individual farmers	Joint coordination, identification of specific constraints of cassava production and processing, joint experimentation, learning from outcomes and adoption. Work procedure is open knowledge sharing and joint action to address institutional constraints.	* Innovation platforms of local value chain actors * District agricultural development unit that now plays an advisory role to innovation platform leaders * A platform lobbying force for linking to urban markets.	Aggregation (accepted new arrangement) Alteration (modifying existing institutional arrangement of engaging farmers) during project implementation phase	A district agricultural and development unit that is well vested in the innovation platform approach to research and extension but lacks the resources and legitimacy to institutionalised approach in the unit

The district agriculture unit accepted the new institutional arrangement. The actors felt the arrangement was a better way of engaging with farmers, because '*everybody will come to the field and experiment together*'. With the completion of the project, the new institutional arrangement could not be sustained, because the unit does not have the funding and the legitimacy to change its governance structure, that authority comes from the national Ministry of Food and Agriculture.

Table 3: Summary of institutional arrangement at value chain level

	Institutional change at value chain level, promoted by IP				
	Existing institutional arrangement	**Promoted new institutional arrangement**	**Enacted institutional change**	**Bricolage practices during project**	**What will plausibly remain after project?**
DONATA (IP)	Use of few cassava varieties Weak linkages among value chain actors Practice of planting in round mounds	* New cassava varieties are made available and to be used for different purposes * New cassava production practice of planting in long ridges. * Environmentally processing practices with supported equipment and technology * New linkages through formation of innovation platforms	*New cassava varieties used for different purposes * What new production and processing practices emerged/enacted? *What new linkages between farmers, processors, input dealers, transporters, and local buyers emerged?	Aggregation Articulation	* Established linkages between local cassava value chain actors; and social networks that extend beyond cassava into the production and processing of other crops (e.g. yam, maize)

5. Analysis and Discussion

In this section we return to the aim of this paper that is to understand institutional innovation processes of PBPs for value chains. It has become a common agenda for agricultural projects to form collaborative partnerships as a strategy to transform value chains, and thus achieve broader developmental goals like poverty reduction and food security (Glasbergen, 2007). These PBPs are a method to build networks, mobilise resources and collective action to design new institutional arrangements that are presented as the solutions to identified constraints in value chains. When studying the PBP cases, we see quite some mobilisation differences between the PPP and IP projects: they are initiated and led by a different type of IEs; they have a different focus; and tend to mobilise a different set of IE partners (refer to Figure 2):

- *IE Focus*: Donors and NGOs, as first stage IEs, preferred a PPP arrangement with clear contractual commitments related to the envisaged institutional change. Aim of the PPP project was to create substantial change at value chain level. Researchers, as first stage IEs, focussed on IPs as new institutional arrangement for more (smallholder) inclusive Research and Development (R&D) collaboration. The task and focus of the IP collaboration was less clearly defined than in the PPP contracts: In the *DONATA* case the IP collaboration should enhance local development.
- *Focal persons*: As focal person for the formation and coordination of the PPP project, donors and NGOs recruited experienced development practitioner with good communicative qualities, as focal person. For the formation and coordination of the IP the researcher IE recruited someone within the government system: a respected researcher of national agricultural research institute or government officer, responsible for agricultural planning and extension. This makes sense as the project aimed to (inspire) change the national R&D arrangements.
- *IE resources*: In the stages of project initiation and formation, all IEs used their reputation, diagnostic and some prognostic framing to mobilise partners for a proper articulation of the project. At the 3rd stage, however IEs had to mobilise partners to considerably invest in the execution, and to attain this, they needed to complement the prognostic framing with more actor-specific motivational framing and some financial incentives. In both cases funding for implementation was needed, but it played a major role in the mobilisation of PPP partners.
- *Partner mobilisation dynamics*: The donor-initiated *CORIP* PPP project mobilised government officers and NGO development experts to provide guidance as members of the consortium and advisory body, while contracting private actors for the concrete implementation. As *DONATA* focused on local development, they mobilised the government, local NGO and farmer leaders at district and village level. (Figure 2)

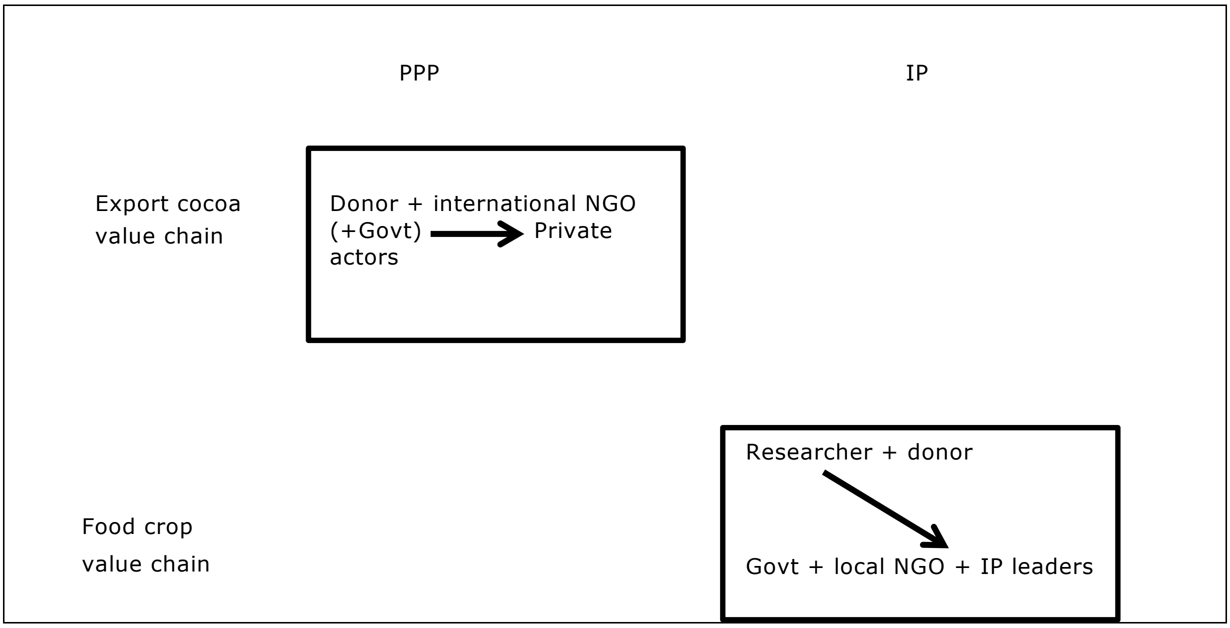

Figure 2*:* IE mobilisation dynamics to higher level or lower level actors in case studies

In both cases, the new institutional arrangements for institutional innovations in value chains were crafted based on the vision of the project initiators, without much attention to the realities of the institutional logics of the field-level implementers. Institutional innovation process of the PBP was thus a top-down process, with pre-defined institutional arrangements for fixing development in value chains. The introduced institutional arrangements went through bricolage practices. As the field-level implementers build on rules, practices and routines, embedded in their institutional logics to pick from the introduced arrangements what best fitted their interests. The PPP tend to trigger articulation, while the IP triggered aggregation as bricolage practices. These practices thus constrained the openness and outcomes of IE. The introduced new institutional arrangements in some cases did not lead to their expected outcomes, but PBPs must not see these as failures, because they are important components of the reproduction of institutions (Garud et al 2002).

6. Conclusions

IP and PPP initiatives in Ghana emerged for different value chains (export and food crop), due to different kinds of concerns, which warranted different development practices. Both collaborative arrangements managed to mobilise key actors for inclusive development, though private companies are hesitant to join IPs. IPs provide good opportunities for networking, knowledge sharing and learning for institutional innovation. The impact can be substantial in a food crop value chain; but the impact is very locality specific. To out-scale the lessons learned, PPP seem a valuable approach. PPP projects are able to mobilise key actors, including larger private companies. The long term success of a PPP depend partly on the expertise, network and financial resources of the initiators, partly on the position and reasoning of the field-level implementers as the latter will always try to adapt the 'rules of the game' to make them fit to their institutional logics and interests. Policy interventions should support dynamic institutional entrepreneurship of PBPs, based on the value that the different actors bring to the overall functioning of specific partnerships.

As this was a very exploratory research and the first in its kind, more research is needed into mobilisation dynamics, bricolage and development effects in different countries and value chain contexts, to get a better overview.

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INNOVATION AND INCLUSIVITY IN DEVELOPING ECONOMIES: THE GENDER PERSPECTIVE

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Abstract

The paper argues that innovation inclusivity is one of the key avenues by which individuals at the base of the economic pyramid (BoP) can be brought out of poverty and gender disparities addressed in socio economic development. It further summarizes the linkage between innovation and inclusiveness and elaborates on the role innovation inclusivity contributes to the Sustainable Development Goal on Science Technology and Innovation (STI). Analysis of gender blind innovation challenges is presented with examples from developing economies. Some policy recommendations are (i) Gender blind institutional frameworks including laws and regulations governing intellectual property rights should be substantially changed and (ii) traditional and religious leaders in developing economies may have to change institutional frameworks before gender disparities in innovation can take off.

Introduction

Background

Innovation is one of the key instruments by which individuals at the base of the economic pyramid (BoP) can be brought out of poverty. Poverty manifestations include hunger and malnutrition, limited access to education and other basic services, social discrimination and exclusion as well as the lack of participation in decision-making. Innovation is systemic coming through the processes of the interactions of critical actors performing identifiable functions and connected in various relationships (Juma & Lee, 2006). Innovation is crucial for development as it makes a difference in addressing urgent developmental challenges such as providing access to drinking water, eradicating diseases or reducing hunger. In world history, the first major technological innovation was the development of agriculture as far back as 9000 BC, followed by the development of pottery in about 6000 BC.

Other important innovations were the development of the plow and irrigation between 5000 BC and 4000 BC, which facilitated growth of the world population (Fogel, 1999).

The development of metallurgy and writing dates from around 3000 BC. The development of mathematics dates from about 2000 BC. The history of the emergence of transformative innovations illustrates the cumulative nature of innovation (Fogel, 1999).

Innovation development within countries varies and the Global Innovation Index provides an opportunity for countries to be ranked according to their level of innovation development. Table 1 below provides the Global Innovation Index for selected developing countries. Rankings of the selected countries shows that there is more room for improvement with respect to innovation development (Global Innovation Index Report, 2015).

Table 1: Global Innovation Index Rankings for selected developing countries

Country	**Global Innovation Index Ranking**
South Africa	60
Kenya	92
Malawi	98
Ghana	109
Uganda	111
Gambia	112
Cote d'Ivoire	116
Tanzania	117
Zambia	124
Ethiopia	127
Nigeria	128
Zimbabwe	133
Togo	140
Congo	-

Source: Global Innovation Index Report, 2015

Problem Statement

The concept of inclusive innovation (ININ) emerged in developing countries where poverty of a large portion of the population caused their exclusion not only from the benefits of technological advancement but also from the satisfaction of their basic needs (Heek et al., 2013).

Scientific evidence shows that, gender inequality and innovation issues cannot be separated from actions that tackle poverty, hunger, poor health, maternal death, climate change adaptation, energy, environmental burdens, economic hardships, and societal insecurity. This is because innovation outcomes are influenced by biological and social differences between females and males. Most developing economies have gender blind innovation systems that hinder innovation inclusivity. The motivation for this study was as a result of the growing scientific consensus to integrate gender as a dimension of innovation and inclusive growth issues in developing economies.

Objectives

The general objective of the study was to access innovation and inclusivity in developing economies with a gender lens.

The specific objectives of the research were to:

1. Investigate some gender blind innovation systems prevailing in selected developing countries in terms of:
   - ✓ Innovation policies
   - ✓ Innovation ideas generated by women
   - ✓ Level of education and representation of women in Science Technology and Innovation.
   - ✓ Role of women in innovation system
   - ✓ Utilization of women's innovative ideas within organizations
   - ✓ Innovation support institutions and services
   - ✓ Innovation institutional framework
   - ✓ Infrastructure

2. Provide antidotes to identified gender blind innovation challenges in the form of policy recommendations.

Relevance of the research

Both men and women have a critical role to play in innovation development in developing economies. The research which seeks to provide a gender perspective to innovation inclusivity in developing economies would uncover the gender blind innovation challenges that hinder inclusive innovation development.

The findings would be a source of vital information for governments of developing economies, as by implementing the policy recommendations would promote development for all.

This research did not exhaust all the gender blind innovation challenges in developing economies because the research was limited to only ten countries. This paper would also be a motivation for other researchers particularly, gender expert working in the area of science, technology and innovation (STI) to expand the study countries.

Finally, the research would contribute to existing knowledge in innovation and gender.

Literature Review

Definitions of innovation inclusivity

Several definitions of innovation inclusivity have been proposed. The World Bank defines inclusive innovation as "knowledge creation and absorption efforts that are most relevant to the needs of the poor" (Dutz, 2007).

Heeks et al. (2013) also defines inclusivity in innovation as "being involved as an actor in the innovation process, being considered as relevant for the innovation, being involved in the adoption of innovation or simply benefiting directly or indirectly from the innovation".

According to OECD (2015), 'Inclusive Innovation' refers to the knowledge creation, acquisition, absorption and distribution efforts targeted directly at meeting the needs of the low-income population. The focus of inclusive innovation is on delivering high performance products and services or high experience at ultra-low cost to the people whose needs are generally not addressed. Thus innovation leads to inclusive growth, which does not exclude certain classes of society such as women, men, disadvantaged etc.

Inclusive innovations have different dimensions namely pro-inclusive innovations and grassroot innovations as detailed below:

"*Pro-inclusive innovations*" often modify existing technologies, products or services to supply lower and middle-income groups. Among them, "frugal" innovations allow setting lower unit product prices by preserving only the most critical functionalities, while retaining core quality characteristics. The lower price allows lower-income groups to purchase those innovations. Examples of pro-inclusive innovations include the Tata Nano (in the goods category), a low-cost, no-frills car produced in India. Many different actors, including micro, small and medium enterprises, large domestic corporations, multinational enterprises, state enterprises and not-for-profit corporations, have introduced pro-inclusive innovations (Kaplinsky, 2011).

"Grassroots innovations" are inclusive innovations emphasizing the empowerment of lower-income groups. While they are undertaken by the poor, they can be supported by other actors in the innovation system, including universities, non-governmental organisations (NGOs) and private firms. Poor populations can be involved through minor roles (e.g. as product distributors) or more extensive ones (e.g. as joint producers) (Heeks et al., 2013).

Gender relations within inclusive innovation

Innovation outcomes are influenced by biological and social differences between females and males, hence the growing scientific consensus to integrate gender as a dimension of innovation and inclusive growth issues in developing economies (Schiebinger, 2008).

Innovation is closely related to risk and uncertainty. One cannot innovate without taking risky decisions. Unlike financial and economic literature, there is a large body of work on risk aversion in social and psychological experimental studies, which analyze differences in terms of risk-taking between men and women. Women appear more risk-averse than men and therefore less innovative (Eckel & Grossman, 2008).

Contribution of innovation inclusivity to the achievement of the Sustainable Development Goal (SDGs) on Science Technology and Innovation (STI)

Debates on how best to promote sustainable and inclusive development in countries are incomplete without a full consideration of issues on STI. Access to new and appropriate technological innovation promote steady improvements in living conditions, which can be lifesaving for the most vulnerable populations, and drive productivity gains which ensure rising incomes. The SDGs are important encapsulations of the fundamental needs for socio-economic and environmental development including poverty reduction, food and nutrition security, good drinking water, healthcare and reduction of climate change impacts.

Key SDGs relevant for the innovation and inclusivity discussions are summarized below:
Goal 1: End poverty in all its form everywhere.
Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture.
Goal 3: Ensure healthy lives and promote well-being for all at all ages.
Goal 4: Ensure inclusive and quality education for all and promote lifelong learning.
Goal 5: Achieve gender equality and empowering all women and girls
Goal 6: Ensure access to water and sanitation for all.
Goal 9: Build resilient infrastructure, promote sustainable industrialization and foster innovation.
Goal 10: Reduce inequality within and among countries.
Goal 16: Provide just, peace and inclusive societies.
Goal 17: Revitalize the global partnership for sustainable development (WISET, 2016).

Two SDGs, Goal 9 and 17 directly focuses on scienc technology and innovation. This is because without Science Technology and Innovation, industrialization will not happen and without industrialization, development will not happen. Each of the goals have specific targets.

Targets for SDG Goal 9 focusing on innovation development are presented below:

- ✓ Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries by 2030, encouraging innovation and substantially increasing the number of researchers and development workers per one million people, in addition to public and private research development spending.
- ✓ Support domestic technology development, research and innovation in developing countries including by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities.

Targets for Goal 17 focusing on innovation development are:

The targets for goal 17 with specific reference to technological innovation are presented below:

- ✓ Enhance North-South, South-South and triangular regional and international cooperation on and access to science, technology and innovation and enhance knowledge sharing on mutually agreed terms, including through improved coordination among existing mechanisms, in particular at the United Nations level, and through a global technology facilitation mechanism.
- ✓ Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed.
- ✓ Fully operationalize the technology bank and the science, technology and innovation capacity (WISET, 2016).

As gender issues have relations within innovations, efforts have been made to address inequality in the implementation of the SDGs. Recommended gender knowledge required to achieve each SDG have been documented to enhance successful implementation. Specifically, some of the recommended gender knowledge required to achieve SDG goal 17 on STI includes the following:

- ➢ carrying out gender differentiated impact assessment on all policies related to STI for development to ensure they benefit both men and women equally; and

- ➢ researching on the institutional innovations that identifies local problems and needs for dealing with gender issues.

The nature of innovation is important in bringing about inclusivity. Agriculture innovation is an important means of ensuring improvement in the socio-economic circumstances of farmers. Alliance for a Green Revolution in Africa (AGRA) Soil Health Program brought out innovations for farmers that enhanced on-farm productivity for various commodities. In some farmer-managed demonstrations, maize yield of 5 MT per hectare was achieved compared to the usual 1 MT per hectare. For pigeon pea, the yield on farmer-managed demonstration farms was 4 MT per hectare compared with 0.8 MT per hectare. For soybean, the yield was 3 MT per hectare instead of 0.6 MT per hectare (Kiwia et al, 2016).

Clearly the innovation impact was not only in terms of the types of seeds grown, nor the management of the soil nutrients but also the system of using farmers to exhibit the gains of the research outputs and deepening the understanding of the improved farming techniques for yield increases. In what AGRA terms "Going Beyond Demos" (GBD), there is an institutional innovation which underscores the importance of field demonstrations managed by farmers. GBD is a broad concept that encourages farmer adoption of technologies through the realization of the benefits and the removal of systemic constraints against farmer adoption (Kiwia et al., 2016). It is in the promotion of these kinds of innovations that chances of achieving the SDGs can be enhanced especially in relation to poverty reduction, food and nutrition security and sustainable livelihoods.

Conceptual framework

The study builds on the theories and concepts of inclusive innovations, gender relations within innovations, innovation policies in developing economies, stereotyping innovation ideas and the innovation ecosystem in general to develop a conceptual framework for the study. The conceptual framework has seven components (figure 1).

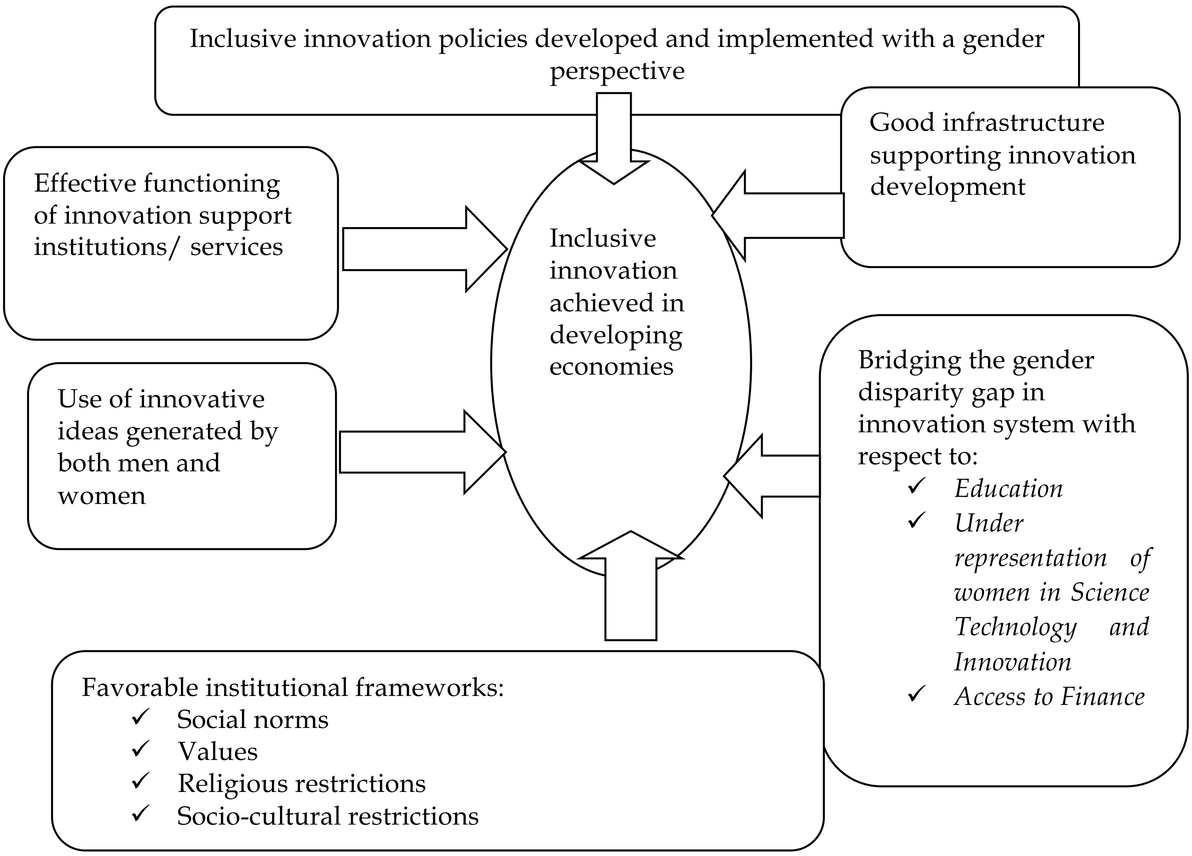

Figure 1: Conceptual framework
Source: Authors own construct

The framework was developed with a strong conviction that inclusiveness innovation can be achieved in developing economies through a combined factor, as innovation is systemic. The effective functioning and interaction of these factors within the innovation ecosystem is very critical. Notable among these factors are the seven components listed below: (1) Inclusive innovation policies developed and implemented with a gender perspective (2) Effective functioning of innovation support institutions (3) Use of innovative ideas generated by both gender (4) Good infrastructure (5) Bridging the gender gap in innovation systems (6) Use of innovative ideas generated both gender (7) Favorable institutional frameworks.

Details of the role each component in the conceptual framework plays to contribute to achieving inclusive innovation in developing countries have been discussed in the discussion section of this paper with emphasis on the gender blind areas for policy action.

Methodology

This section provides a description of how the study was conducted and focuses on the sampling technique, data collection method and data analysis.

Sampling design

The simple random sampling technique was used in selecting 14 developing countries for the study. The lottery method was used to select fourteen countries randomly from the UN developing countries classification list. Selected countries were South Africa, Nigeria, Kenya, Ghana, Tanzania, Uganda, Zambia, Gambia, Zimbabwe, Malawi, Cote D'Ivore, Ethiopia, Congo and Togo.

Data collection method

Secondary data were mainly used for the study. Secondary data were obtained from reports such as the Spring Global Attitude Survey 2014 Report, UNESCO Institute for Statistics 2015 Report and Global Innovation Index 2015 Report.

Data analysis methods

Content analysis was used to synthesis both quantitative and qualitative secondary data for the study.

Discussions

Innovation policies

Most developing economies have gender blind innovation policies that hinder innovation inclusivity. Innovation agendas in the developed and developing world differ significantly. The drivers for innovation in the developed world have been centered on getting more (performance and productivity) from less (physical, financial, human capital) for more (profit, value to the shareholder). In contrast, the drivers in the developing world are to get more (performance, productivity) from less (cost) for more (people). In other words, innovation in the developing economies has to focus on "inclusive growth" hence the importance of "inclusive innovation" policies (OECD, 2013).

The rationale for innovation policies is that, they aim to boost technological change, which is considered the basic factor of economic growth, social development, and environmental adaptation. Most developing countries are very poor in developing inclusive innovation policies. Science Technology and Innovation policy have often been pursued independently of the broader developmental agenda and without gender perspective. Implementing innovation policy with a gender perspective is even more daunting in developing countries where the institutional context is more difficult, resources are limited, and managers are unable to carry out these programs (OECD, 2013).

Again, women tend to be excluded in STI policies and decisions, which often do not reflect their specific needs and concerns. It is therefore critical that their interests and concerns be reflected in efforts at harnessing innovation for development by applying a gender lens (Huyer & Nancy, 2007).

Stereotyping innovative ideas generated by women

Some feminist researchers carry out an in-depth analysis of innovative behavior in organizations and highlight a biased vision due to stereotypes. Foss and Moilenen, (2013) show that, women are as innovative as men in generating new ideas. According to Cooper (2012) women are not perceived as innovators, their ideas are not put forward and therefore not implemented, this means that women are not lacking innovation capabilities but stereotypes interfere. Alsos *et al.*, (2013) suggest that, the question that could be answered is not who is creative but rather who has the power in organizations and who is listened to. It points to the efforts to elaborate on institutional innovation, which basically concerns addressing systemic constraints in the promotion and use of technologies.

In most developing economies, due to socio cultural dynamics, women's role as innovators were formally less acknowledged than that of men in formal Science Technology and Innovation development approaches. Increasingly, however, the innovations developed by women to address some of the challenges in the agriculture, water and energy sectors are becoming more recognized and documented (Schiebinger, 2010).

A common constraint in promoting innovation is the lack or inadequate finance which hinders adoption of innovations in developing countries. In a large number of developing economies, financing innovation development and adoption of innovation by end users is a challenge. Without access to credit, especially women farmers may be unable to bear the risks and up-front costs associates with innovations and investments necessary to enhance their productivity, income and well-being (Schlesinger, 2010).

Comparatively, women in developing countries are less likely to finance the use or purchase cell phones than men. The mobile phone is a means of disseminating technological information such as agriculture and health extension messages such as prices of agricultural products, weather information, anti-natal information for pregnant mothers.

A survey conducted across the following seven countries in 2014, South Africa, Nigeria, Senegal, Kenya, Ghana, Tanzania and Uganda revealed that men are more likely than women to own cell phones in the six out of the seven countries except in South Africa where no gap was observed. For example in Uganda 77% of the men owned cell phones with only 54% of women owning cell phones (Pew Research Centre, 2015).

Low levels of education and under representation of women in STI.

Education is a key part of strategies to improve individuals' well-being and societies' economic and social development. Education improves labour quality to successfully adopt innovations. However, educational levels of majority of women in developing economies are very low than men and this is a significant barrier to the management, development and adoption of innovations. Educating women is a powerful weapon in fighting global poverty. However, females have been the most affected with little or no access to educational opportunities which can be attributed to social, traditional and deep-rooted religious and cultural beliefs that are often the barriers they encounter and unable to overcome (Masanja, 2010).

Currently, females are under-represented both in school enrollment and attendance in developing countries and this has negative implications for innovation development. Another challenge hindering inclusive innovation development in developing economies is the under-represented of women in science fields (APGEST, 2002). Table 2 below illustrates the percentage of female science researchers in selected countries. It will be observed that for the selected countries, the percentage of female science researchers were below 50%.

Table 2: Percentage of female science researchers in sampled countries

Percentage of female science researchers in sampled countries		
Countries falling below 50 percent (%)	**Countries**	**Percentage (%)**
	South Africa	43.7
Countries falling below 40 percent (%)	Zambia	30.7
Countries falling below 30%	Kenya	25.7
	Tanzania	25.4
	Zimbabwe	25.3
	Uganda	24.3
	Nigeria	23.3
Countries falling below 20%	Gambia	20.0
	Malawi	19.5
	Ghana	18.3
	Cote D'Ivoire	16.5
	Ethiopia	13.3
	Congo	12.8
	Togo	10.2

Source: UNESCO Institute of Statistics, 2015

Additionally, there is a decreasing representation of women in STI from secondary school to the university which is a challenge. Low number of females students graduate in science programmes within universities in developing countries. The case was true for female students who graduated in science programmes at the University of Cape Coast, Ghana in February, 2016. Table 3 below shows the distribution of students by gender graduating from the schools of agriculture, biological and physical sciences. It can be observed that for all the school, male students were comparatively higher than the females with the lowest of 93 recorded from the school of agriculture.

Table 3: Distribution of February, 2016 graduating students in science programmes at University of Cape Coast, Ghana.

Name of School	**Male**	**Female**	**Total**
School of agriculture	534	93	627
School of biological sciences	1024	426	1450
School of physical sciences	2267	461	2728

Source: UCC Student Records and Management Information Section, 2016.

Weak role of women in the innovation systems

Innovation processes germinate and develop within what are called "innovation systems." These are made up of private and public organizations and actors that connect in various ways and bring together the technical, commercial, financial competencies and inputs required for innovation. It is in such systems that government innovation policies are focusing. Women play a weak role within innovation systems than men in most developing countries, key issues hindering their inclusion are certain preconditions for participation (such as level of education, women's under representation at senior management levels, inadequate access to venture capital and financing, and limited knowledge of business and intellectual property rights management (UNDAW, 2010).

Huyer & Nancy (2007) reported that a key entry point for women into innovation systems in most developing countries is through private enterprise, both formal and informal. The under-representation of women at the top levels of the business sector is also believed to contribute to weak national innovation systems and less competitiveness in the global innovation system.

For women farmers, small-scale producers, managers and executives the key obstacles are basically the same: lack of access to technical and scientific education and training, lack of access to venture capital, lack of recognition of and protection of women's knowledge and innovations; and lack of training of women for enterprise development (UNCTAD, 2002).

Underutilization of women's innovative ideas within organizations

Companies in developing countries also have few women as innovation managers or in leadership positions in businesses to spearhead gender sensitive innovations in businesses. It is worth mentioning that, women's ideas are usually not supported as much as the ideas of their male colleagues within organizations. Thus there is a lack of collegial support in implementing women's innovative ideas. For example in sub Saharan Africa, women representation in senior management in business is 22% (Farnworth, 2010).

Innovation support institutions or services

Science Technology and Innovation support institutions do not function effectively in most developing economies and tend to be of poor quality, with inadequate equipment and a poorly remunerated staff coupled with gender imbalance in staffing**.** Supporting innovators effectively requires putting the necessary technical, commercial, and other services as close as possible to them. Such services should therefore be organized locally through the efficient mobilization of concerned authorities and with the active participation of concerned "clients." Services of strategic relevance for innovation policy include basic industrial services like promotion, marketing, technology extension services, standards, testing, quality control, information and communication (Prabhu, 2014).

Innovation institutional framework

In inclusive innovation processes, institutions play a critical role. They determine the extent to which the poor are able to participate in the innovation process and share in the potential benefits. Institutions include social norms of behavior, habits, routines, values, and aspirations, as well as laws and regulations, all of which are rooted in a given society's history and culture (Mashelkar, 2014).

The importance of institutions to innovation processes creates several challenges for poor men and women. The institutional framework in developing countries are unfavorable not gender friendly to promote equity in the access to innovation. For example access to assets such as land or credit may be difficult or impossible for the poor, women and some disadvantaged men in most developing economies (UNESCO, 2007).

Owing to certain norms, poor women may be prevented from taking certain roles required for innovation and also social stratification may block the formation of the social networks needed for innovation. Because of existing customs and cultural characteristics, new innovations are not always accepted by persons of lower income who are mostly women.

Low levels of education combined with tradition and fear to move away from customary methods of living may make the acceptance of innovation in the form of new products, processes or business methods challenging (Meinzen-Dick et al., 2010).

For example, in social context where meetings between a women and men from outside the family nucleus are restricted, women access to innovation is limited. In Ghana, for example, extension agents tend to approach male farmers more often than females farmers because of cultural restrictions and also because of the general misconception that extension advice will eventually "trickle down" from male heads to other household members (Meinzen-Dick et al., 2010).

Infrastructure

The poor conditions of infrastructure in developing countries are also core issues in managing innovation. Social infrastructure such as telecommunications, schools, colleges, universities, healthcare facilities, and other infrastructure like water and power supply etc. are still not well developed in the developing countries to meet the challenges and requirements of innovation and technology management. Economic infrastructure relating to transport like roads, highways, trains, buses, airports, are inadequate making it costly for companies to serve poor customers. Innovators may find it difficult to reach end users of innovations living in the hinterlands thus distance becomes a barrier to innovation dissemination. Nevertheless, information and communication technologies (ICTs) have offered new opportunities for inclusive innovations. Examples are mobile money transfer services operating in Kenya, Ghana and other developing countries (Alder & Uppal, 2008).

Conclusion and Policy Recommendations

Conclusion

From the study it could be concluded that, gender gaps exist within the key factors that must interact to achieve innovation inclusiveness in developing countries. Developing economies have the strong potential for achieving innovation inclusivity to spur inclusive growth if gender perspective is incorporated in innovation development. Applying a gender lens to innovation development by government in developing economies is critical for poverty reduction.

Policy recommendations

The following recommendations when implemented would promote innovation inclusivity: Governments of developing economies should develop "gender inclusive innovation policies" which involves applying the gender lens in each phase of the policy making process or cycle thus from the design, implementation, monitoring and evaluation. In the validation of the policy, efforts should be made by policy makers to involve women networks, gender experts, women groups in policymaking at national and international policy forums.

Inclusive innovation policies should then be translated into projects that directly serve the welfare of lower-income and excluded groups while taking into consideration the needs of end users. This requires conducting gender needs assessments to identify innovation needs of men and women to inform programme or project design. This is because top-down, supply-driven innovation initiatives have often proved ineffective for addressing the innovation needs of the poor especially women.

Government should set up Inclusive Innovation Fund (IIF) at the national level to support innovators and enterprises in developing their ideas to the point where they can raise private finance by proof of concept or through prototyping and marketing development. This will improve the welfare of people in the lowest income group especially women.

Gender blind institutional frameworks should be substantially changed by governments in developing economies. Again, governments should ensure that regulatory impediments do not prohibit or constraint innovations serving the poor particularly with regards to public service, while still ensuring critical quality standards are being met.

Traditional and religious leaders should discard socio cultural norms, values and aspirations, religious norms which are rooted in a given societies culture and religion that prevent women from adopting innovations.

In order to increase the role of women in innovation, it is necessary for governments to ensure greater access of women to education, capital and markets to improve their livelihoods. Women need to be supported in entrepreneurial development, not only in micro and small sized enterprises, but also in large sized enterprises, as a means to promoting their involvement in innovation. This includes providing advice and training, better access to markets and financing, and technology support in production and quality processes.

In addition, it means ensuring women's representation at senior management levels, and that they acquire sufficient knowledge of business and intellectual property rights management.

Governments in developing economies should also take initiatives to improve existence infrastructure and develop new infrastructure. Public research laboratories should be equipped to respond efficiently to the needs for technical research, technical assistance, certification, and quality control functions.

Ensuring access to STI education and technological skills through formal means to support women become research scientists, technologists and innovators should be the priority for governments. Through women's participation in science, technology and engineering education, workforce and leadership, women can contribute to shaping the STI agenda to make it more gender-responsive.

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CHALLENGES AND OPTIONS OF INNOVATION RESEARCH IN DEVELOPING COUNTRIES: A REVIEW OF AGRICULTURAL INNOVATION RESEARCH AND INVESTMENT IN GHANA

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Abstract

Agricultural innovation is considered one of the pathways to enhance agricultural growth since it improves productivity and competitiveness. This paper sought to assess the challenges hampering the growth of agricultural innovation research in Ghana. A literature study approach was employed in gathering data for the period 2000 – 2015. The findings indicate that, government budget on the agricultural sector has consistently increased except 2009. It was revealed that while spending on agricultural R&D has significantly improved, especially during 2003-2014, evidence suggests that ARI ratio has consistently been less than 1% over the period under consideration. There has been a steady growth in number of agricultural researchers over the years, however, this is considered inadequate. It is recommended that government should continue to increase public spending on agricultural R&D with more focus on on-farm productivity enhancing activities. Research institutions should diversify their sources of funds by partnering with the private sector to consider options such as producer export levies on export/commercial crops and commercialization of research outputs. Prioritising the training of more qualified scientists, technologists and innovators to fill existing and anticipated staffing gaps to sustain the gathered innovation momentum is emphasized and complemented by staff motivation and recognition of outstanding scientists.

Keywords: Agricultural innovation R&D, R&D expenditure, agricultural researchers

1.0 Introduction

1.1 Background

In spite of the increasing wealth globally, studies show that some people in developing countries, especially in Asia and Africa, still go to bed on hungry stomach (FAO, 2015). Alongside this, is an increasing rate of poor people in urban and rural communities. Compounding the problems of these countries are the effects of the teeming growing populations in the midst of endangering scarce resources and employment (*ibid).* In view of this, some have proposed massive investment in innovations that are able to propel poor nations out of the poverty which seems to have engulfed them (Beintema and

Elliot, 2009; Asare and Essegbey, 2016). As a way out of the situation, some technologies have been developed and circulated among farmers and other food producers. Yet the results have been discouraging and this is evident by the current figures of poverty and food and nutrition insecure people of the world (FAO, 2015). These poor and negative situations have generated the desire among policy makers and governments to reduce the pervasive hunger and malnutrition (see World Bank et al., 2009) through a reduction of the high food import outlays which have bedeviled the economies of some of these poor and developing countries, especially in Africa and Asia.

In a bid to resolve some of these challenges, some governments of the Africa region are adopting the Comprehensive Africa Agricultural Development Programme (CAADP) developed by Heads of State and Government in Africa. The purpose of the CAADP is to use agriculture-led development as a fundamental platform to reduce hunger, poverty, and the burden of food imports while generating economic growth and creating the way for expansion of food exports. To achieve high results, participating countries are in the process of identifying research and adoption priority mechanisms to disseminate agricultural research and development outputs for better outcomes. These priorities form the basis of the imports of the Forum for Agricultural Research in Africa (FARA), the regional coordinating research body and other research and development organizations working in Africa. Innovation research therefore becomes a top priority for national economies. This paper seeks to address the questions such as whether; the level of investment in agricultural R&D and innovation in the country is adequate; does Ghana have the human resource capacity to harness agricultural innovation to raise productivity in the agricultural sector and are public research institutes' laboratories adequate enough for agricultural innovation research in the country?

1.2 Problem statement

A major challenge of developing countries governments is how to significantly reduce poverty. In 2013, 12.6% of people in developing countries live below USD 1.9 a day poverty line, with SSA leading (41%) (World Bank, 2016). In spite of the fact that poverty has reduced significantly in Ghana from 51.7% in 1991/92 to 24.2% in 2012/2013 (GSS, 2014), the incidence of poverty is high especially among food crop farmers (MoFA, 2007). This has been attributed to the absence and use of basic technology as well as poor support from agricultural support services such as credit and other inputs and low yields resulting from poor soil fertility due to nutrient depletion, heavy soil mining and low input use and low application of improved technologies (MOFA, 2007; Martey et al., 2013; Ragasa et al., 2013). This begs for the use of modern technologies, which have proven records.

Investment becomes critical in this direction as R&D are capital intensive, considering human resources and other logistics and facilities needed. This requires investment and support from R&D institutions in innovations and driven by favourable governmental policies. Yet while government pledged to spend 1% of GDP on R&D, actual spending oscillates in the range of 0.3% – 0.5% of GDP (UNCTAD, 2011; MEST, 2010) due to poor economic indicators. This corroborates the inadequate budget and resource allocation that characterize STI application in the country (MEST, 2010). There is high dependence on donor funding for research but these inflows are erratic in nature. Again while some improvement in public expenditure is recognized and recorded, the said improvement in expenditure does not match that of investment in R&D. This raises questions about Ghana's priority in R&D. While these difficulties exist and plans are underway to solve them, some progress have been achieved which needs to be touted.

Generally, Ghana has made some significant progress in STIs. This has been confirmed by the Innovation Index Report published in 2012. This report suggests that Ghana's position has improved from a rank of 114 (out of 141countries) in 2010 to a rank of 90 (out 141 countries) (OECD, 2013). In a similar argument, innovativeness in the agricultural sector has improved and which has resulted in the introduction of new technologies (see STEPRI, 2008), increased in crop productivity in recent times and growth in household farm incomes as confirmed by several studies (see e.g. Acheampong and Owusu, 2015; Ragasa et al., 2013; Wiredu et al., 2014).

In spite of these successes, there are some potential threats challenging the growth prospects of R&D and innovativeness in the agricultural sector of the country, which deserves critical attention. These include but not limited to inadequate staffing of public research institutes (PRIs), lack of modernization of policies and institutions and misalignment of goals related to human development and economic growth, weak linkages and poor feedback between and among institutions leading to less motivation to collaborate with each other and the inability of educational (science, technology, engineering and mathematics – STEM) institutions to train enough science graduates who are technologically sophisticated to drive innovations for socio-economic growth and development (UNCTAD, 2011; MEST, 2010). These threats are a bane on institutional capacity of the country's STI, and therefore tend to weaken the supply side of agricultural innovation systems of the nation. Others such as inadequate scientists and technologists hinders scientific and technological advancement.

1.3 Objectives

The main objective of this paper is to assess the challenges hampering the growth of agricultural innovation research in Ghana. This is carried out by attempting to achieve the following specific objectives:

- examine the levels of public investment/financing of agricultural R&D and innovation
- analyze the trends in human resource capacity of knowledge institutions driving agricultural innovation research in Ghana.

1.4 Relevance of research

This paper presents a snapshot of the status of national and international support for innovation research for food, nutrition and agricultural development in Ghana. It aims at providing some insights into expenditure and investment patterns of innovation research in the agricultural sector of the country, as a way of exploring and presenting the state of knowledge and management of innovation research in Ghana with the view of making good the country's deficiencies in innovation research and therefore to improve the competitiveness and sustainability of the country's knowledge base in STI. This paper comes at no better opportune time than now, when Ghana is seriously considering buying fully into the STI discourses in the country. It will help improve our understanding of the status of innovation research in the country and role played by the state and international organizations in promoting agricultural and rural development innovations as a way of proposing pragmatic ways for which donors can relate and engage with the state to yield better outcomes.

1.5 Literature review

1.5.1 Agriculture innovations in Ghana

Ghana's agriculture is dominated by smallholder producers, who constitute about 90 percent of farmers in the country, cultivating an average farm size of about 1.2 hectares and applying more of traditional technology and low use of improved technology generally. This has been observed to have resulted in yields that are generally below expectations. This suggests that there is significant potential for improvement. In general, reports about the sector have suggested a major contributor to low yields is poor soil fertility resulting from nutrient depletion, soil mining and low input use, resulting from the high prices of commercial fertilizers and limited availability of quantity and quality organic inputs (manure, crop residues, etc.) to complement the inorganic fertilizer. Yet, fertilizer use in Ghana is less than 8 kg/ha, similar to the average rate in SSA, but significantly lower than in other developing countries (MoFA, 2010). This has been observed to have moved up above 8 Kg/ha in recent times and still tapering. Another major factor of crop productivity is the use of improved seeds and planting material that is suitable for the socio-cultural environments within which the crop is cultivated. Many of such technologies have been developed by CSIR and its agriculture oriented institutes, universities and international organizations (see STEPRI, 2008). However, evidence suggests that publicity, dissemination and assimilation of these technologies have not been encouraging enough resulting in wide gaps between actual and achievable yields. This calls for more commitment to and investment in innovation R&D and technology transfer.

1.5.2 Ghana's agricultural innovation system and its role in innovation research

Agricultural innovation system (AIS) is made up of several dimensions and can denote various levels giving rise to local, sectoral, regional and national types of innovation systems. There are several definitions for AIS but for the purpose of this study we adopt that of the World Bank. An innovation system is a network of organizations, enterprises and individuals focused on bringing new products/technologies, new processes and new forms of organization into economic use, together with the institutions and policies that affect their behavior and performance (World Bank, 2006). Ghana's AIS encompasses actors such as tertiary educational institutions (TEIs), public research institutes, private enterprises, regulatory frameworks and other relevant institutions. These actors together form the National Agricultural Research System (NARS). The actors and the people within them interact through linkages such as research collaborations, personnel exchanges, equipment purchase, cross-patenting and other channels. The Government of Ghana plays the fundamental role of providing infrastructures, relevant ministries/agencies (e.g. MESTI), institutions (both educational and research) and the appropriate regulatory framework with the view that these structures will create the right innovation environment for innovation processes to thrive.

TEIs mainly the UG, KNUST, UCC and UDS not only contribute to human resource development by educating and training research scientists and technologists but they also perform research works. The CSIR and its 13 research institutes constitutes Ghana's main agency for agricultural R&D. Ten (10) of the institutes are directly engaged in agricultural research activities. CSIR sets the main research institutional framework for agricultural technology/innovation development. Other public research institutes such as Cocoa Research Institute of Ghana (CRIG), the Marine Fisheries Research Division and the Biotechnology Nuclear Agricultural Research Institute also conduct research in their respective domains.

AIS of Ghana makes significant contributions to agricultural innovations R&D which has resulted in the introduction of technologies over the decades. A review of literature by CSIR and IFPRI in 2010 indicates that about 109 agricultural technologies/innovations have been generated in Ghana: out of which 91% were developed by CSIR researchers and the rest by Universities (cited in Asare and Essegbey, 2016). Thus AIS plays the fundamental role in ensuring the growth and development of the agricultural sector through R&D and technology transfer to end users. By so doing, it plays the role in job creation, income generation, poverty reduction and in driving Ghana's socio-economic development.

Despite its significance, the enabling environment and financing which will cause AIS to thrive and become vibrant leaves much to be desired. Evidence suggests weak innovation environment and that several impediments stand in the way of agricultural innovation systems and activities. This is discussed in sections 1.5.3 and 1.5.4.

1.5.3 The innovation environment of Ghana

A favourable innovation environment is required for innovation to thrive and support Ghana's socio-economic development. Therefore, the establishment and strengthening of structures, policies, strategies, reward systems among others which are fundamental to innovativeness should be a priority. Ghana has made some progress so far in this regard but using a comprehensiveness index[3], the Economic Commission for Africa concluded that Ghana has an overall weak innovation environment (UNECA/IST, 2012). The index was based on eight sub-policies, Table 1. The figure shows that all the sub-policies indicators scored below 50% with general policy leading with almost 40% and research policy scoring the least. The implication is that the current policy interventions being implemented to create favourable innovation environment are inadequate. The weak innovation environment exemplifies weak innovation activities in the country requiring immediate attention to boost innovation advancement (*ibid*).

Table 1: Comprehensiveness of national innovation environment (%)

Sub-policy indicators	Percentage score (%)
Financing	15
Innovation in education	21
General policy	39
Business environment	25
Counselling and information	12
Promotion of innovation	15
Target groups	19
Research policy	10

Source: UNECA/IST (2012) based on Innovation Survey of Ghana, 2010

1.5.4 Financing innovation in Ghana–the general picture

Financial resource is the life wire of all innovative activities because it offers the means to transform an individual's idea into productive activities (UNECA/IST, 2012). Limited financing slows the pace of innovation progress. Despite the availability of several commercial, agricultural and rural banks, accessing credits/loans from them by farmers is quite challenging due to cumbersome administrative and application procedures, high interest rate and collateral requirements. Therefore, farmers and institutions who want to innovate but need funds are limited by these constraints.

[3] Comprehensiveness index of innovation environment is a percentage score constructed for the sub-policies. A score above 50% was considered as good while a score below 50% was considered as weak (UNECA/IST, 2012).

Figure 1 presents indicators of innovation financing. It is obvious from the figure that Ghana's government has instituted several interventions to support innovation financing in the country. However, these interventions are woefully inadequate as they all scored below 50%. Micro-loans for target groups scored the highest. This may be attributed to the establishment of a number of initiatives and schemes to provide financial support for innovative activities (UNECA/IST, 2012). Established institutions including the National Board for Small Scale Industries (NBSSI), Support Programme for Enterprise Empowerment and Development and Ghana Venture Capital Trust, financially and technically support firms including start-up companies.

The NBSSI with a seed capital from government and development partners operates a revolving fund scheme with interest rate less or equal to 20%, below the prevailing commercial lending rates. Further, borrowers are given flexible loan repayments, two to four months moratorium (grace period) to begin repayment and no demand for collaterals but personal guarantor required to act as loan security.

In 2006, the Government of Ghana established the Microfinance and Small Loans Centre (MASLOC) with the mandate to manage microfinance and small-scale credit schemes to ensure that owners of small-scale enterprises have access to adequate credits. MASLOC provide financing schemes for activities such as tractor purchase and operation, piggery, pineapple cultivation, etc. Flexile repayment schedules are offered to borrowers within one to two years to repay. Additionally, borrowers are given a grace period of one to three months to start repayment depending on the nature of the project and also receive training and capacity building services.

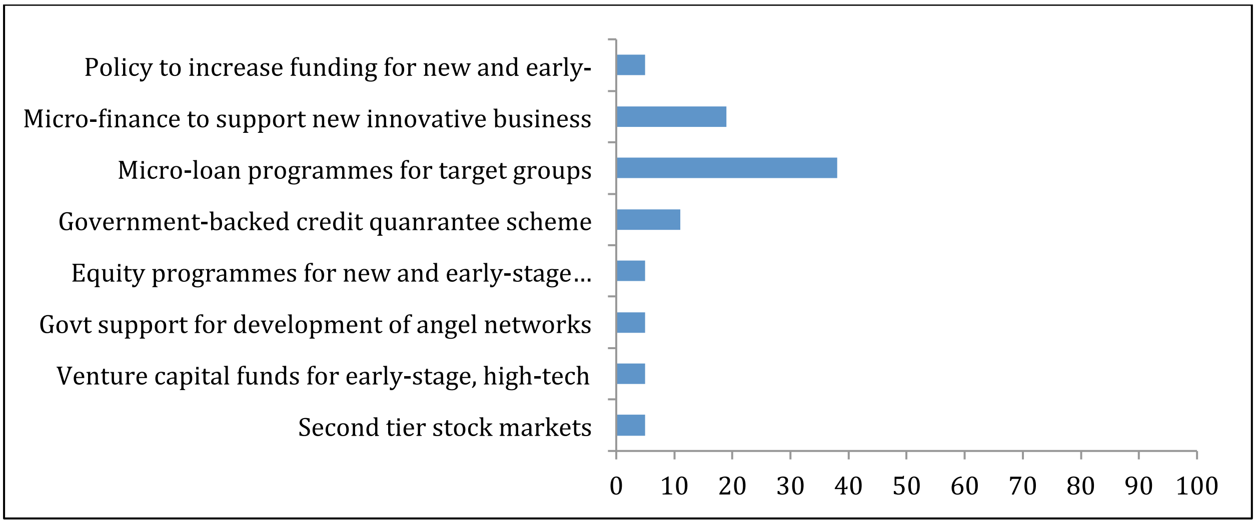

Figure 1: Adequacy of innovation financing, (%)
Source: UNECA/IST, 2012

1.5.5 State of policy and institutional framework on innovation research in Ghana

Policy framework

Innovation policy framework is required to guide innovation research in the country. The policy framework governing STI in Ghana is the National Science, Technology and Innovation Policy developed in 2010 (Revised). The policy drives the nation's vision of creating a strong STI capacity to support the aspirations and socio-economic developmental needs of Ghana's middle–income status. The goal of the STI policy is to harness the nation's total science and technology capacity to achieve national objectives of wealth creation, poverty reduction, and competitiveness of enterprises, sustainable environmental management and industrial growth (MEST, 2010). Ghana seeks to build a robust economy that rides on the wheels of STI for maximum production, processing, manufacturing and industrial activities. Hence, the STI policy was designed with the purpose to bolster Ghana from the present poor STI application practices and the long held perception of Ghana being a traditional economy to a STI and knowledge-based economy. The specific objectives of the policy include: to facilitate mastering of STI capabilities; to create the conditions for the improvement of scientific and technological infrastructure for R&D and innovation. The policy cuts across sectoral boundaries and provides the nation's STI position on specific sectors including agriculture, education, STI and national security, infrastructure, among others.

Institutional framework

In Ghana, National STI policies are managed and implemented by the Ministry of Environment, Science and Technology (MESTI). Thus, MESTI oversees and coordinates research activities and programmes in the country's research institutes and organizations such as CSIR institutes, among others. Additionally, other key government ministries and agencies play significant role in the design and implementation of policies in Ghana, including the Ministry of Food and Agriculture (MOFA) responsible for agricultural sector policy, Ministry of Finance and Economic Planning (MOFEP) responsible for R & D and innovation policies via budgeting, etc. MESTI plays a role via linkage with all ministries to ensure availability of the educated, trained and highly skilled human capital who will be at the forefront to drive the nation's STI, though this role is yet to be institutionalized. But this task has proven difficult over the years due to brain drain because the lack of incentives has resulted in inadequate commitment on the part of the highly trained scientists and technologist (see MEST, 2010). Tertiary institutions are responsible for education and training of experts although their capacity needs to be boosted by government to enable them do more and conduct more R&D.

Policy ensures active collaborations between local and international research institutions to enable local scientists and innovators to take advantage of global knowledge and information. As a result, CSIR now hosts and partners with IFPRI, the International Water Management Institute (IWMI), Alliance for a Green Revolution in Africa (AGRA), etc. Moreover, platforms such as conferences and workshops are organized annually where researchers and contributors to STI present their research findings and make recommendations for policy makers. However, these meetings are usually given little national coverage and so receive little attention from government (*ibid*).

2.0 Methodology

2.1 Data sources and sampling

This study purely relied on existing literature and the period under study is 2000 – 2016. Sources of data include FAOSTAT databases, reports, journals, websites of universities and PRIs and policy document. A purposive sampling approach was used to select 10 public research institutions (PRIs) and 4 universities whose activities involve core agricultural R&D in the country. Quantitative data as well as qualitative information were gathered for the analysis. The main data collected from the institutions included staff numbers (FTEs) and student enrollments in universities (masters and PhD). Additional data employed related to total number of agricultural researchers (FTEs) in institutions across the country, public expenditures on agriculture, spending on agricultural research, agricultural growth rate, and production and area values for selected crops (rice, maize, millet, sorghum, cassava, yam, cocoyam, plantain and cocoa).

2.2 Data analysis methods

The results of the study were analysed using descriptive statistics and graphics analysis. The results are presented in the form of charts and tables. However, an aspect of the study considered performance analysis, which employed comparative analysis, given below.

Performance analysis: targets to compare selected indicators

Selected indicators will be compared with the targets shown in Table 2. According to Beintema and Elliot (2009) the ARI is within the range of 0.2 – 2.5% but for developing countries the more realistic target is 1%. All the descriptive and graphical analyses and computations were done using Microsoft Excel.

Table 2: Targets for comparison of indicators

Target	Description	Target rate (%)
Maputo declaration: Gov't budget commitment allocation to agric	Agriculture expenditure divided by public budget (AE/BUD)	10%
Agricultural intensity ratio (ARI)	Agricultural research expenditure divided by agricultural GDP (ARE/AgGDP)	0.2–2.5%; For DCs = 1%
Agricultural growth rate	Change in AgGDP divided by AgGDP (ΔAgGDP/AgGDP)	6 – 8%

3.0 Results and discussions

3.1 Spending on agriculture and agricultural R&D

3.1.1Agricultural sector expenditure

Public spending on agriculture is crucial considering the size and the traditional role of agriculture in Ghana. Figure 2 presents trends in agricultural expenditure and share of agricultural expenditure in total public budget. In monetary terms, government budget on the agricultural sector has consistently increased since 2001 except 2009, with annual growth rate averaging 33%. Percentage wise, the share of agricultural expenditure in total government expenditure remained a little above 6% from 2001 to 2003 and then increased to 8.9% in 2004. This increase in expenditure share of agriculture is not surprising as it comes in the wake of the Maputo declaration (2003) where African Heads of states and governments urged member countries to commit at least 10% of their annual budgetary resources on agriculture with the sole aim of ensuring agricultural growth of at least 6% annually in the years after. Since 2006 expenditure share of agriculture in total public expenditure shows a rising trend reaching the highest of 16% in 2010 and later falling to 11.2% in 2011. Following the Maputo declaration, the share of agricultural expenditure in total government expenditure has been below the 10% target up to 2008. However, during the 2009 – 2011 period, the 10% target set out in CAADP was attained and exceeded. On the one hand it can be said that Ghana has fared in terms of meeting the target during the last years but on the other hand the question that must be put forward is has the desired growth of 6% materialized considering recent growth in the agricultural sector especially in 2011?

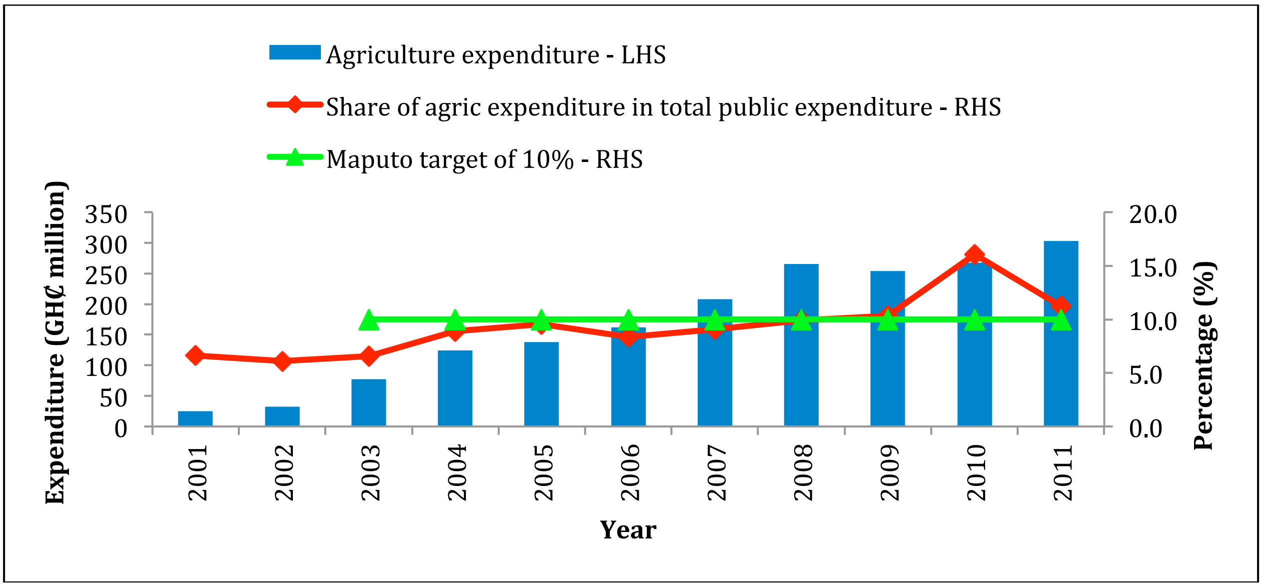

Figure 2: Agricultural sector expenditure in absolute terms and share of agriculture expenditure in total public expenditure in %, 2001-2011
Source: MoFA/SRID, 2013

In terms of sources, the share of GoG in agriculture sector expenditure declined over the years while donor expenditure increased over the same period, Figure 3. However, funding from donor sources is tilted in favour of investment activities though it is erratic.

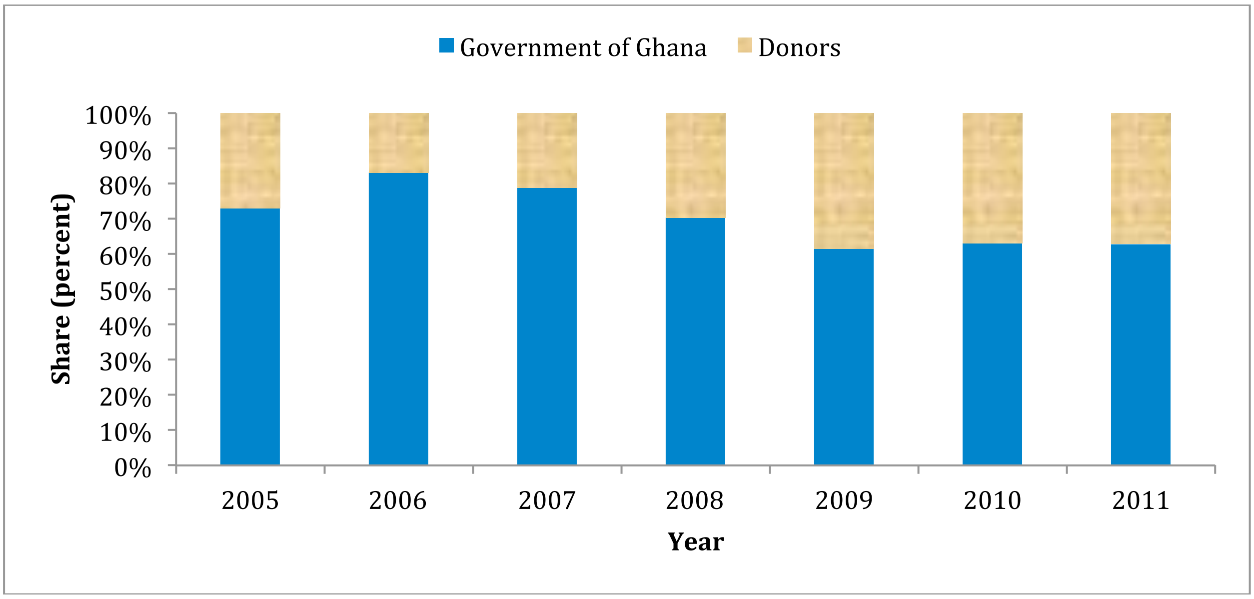

Figure 3: Agriculture sector funding sources, 2005-2011
Source: World Bank, 2013

Most of the sector's expenditure go into payment of salaries and other emoluments and not actual agricultural activities. Evidence shows that while the share of expenditure on investment is increasing that of recurrent expenditure is declining.[4] The share of investment increased from 11% in 2001 to 58% in 2011 (over fivefold increase) while the share of recurrent expenditure declined by half from 89% in 2001 to 42% in 2011 (World Bank, 2013). The declining share of recurrent expenditures (wage and non-wage) raises two issues: *i.* sustainability of the operation and maintenance of investment items and facilities, and *ii.* concerns the adequacy of the provision of technical services delivery in the sector (*ibid*). This suggests there should be a balance between recurrent and investment expenditures to prevent the issues raised.

3.1.2 Trends in agricultural research spending

To generate the desired growth in the agricultural sector, agricultural research has to deliver new and improved technologies capable of yielding continues gains for society. Through sustained growth in agricultural productivity sustainable benefits are achievable through growth in household incomes especially in rural areas, reductions in poverty among the farming population and ensuring food and nutritional security. This therefore requires conscious government investment efforts in public goods that produce innovations in agriculture.

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[4] Recurrent expenditure includes personnel emoluments (wage), administrative expenses, and service expenditure (non-wage).

In absolute terms, there has been consistent increase in total agricultural R & D spending since 2000 (Table 3). Data shows that total agricultural R & D has been less than one million Ghana cedis in the 1980s. In contrast, there has been significant improvement in spending on agricultural R & D especially during 2003-2014 period. This reveals the increased commitment by government to invest in R & D to accelerate agricultural production. In 2014 spending on agricultural R & D was more than ten times the spending in 2003. According to Table 3 agricultural R&D started increasing only after the late 1990's. This is an indication of when the realization to spend in agriculture at the state level began to increase. It coincides with the period where world leaders rigorously began to look for research to solve national challenges.

Table 3: Public agricultural R & D spending (in Gh₵ million), 2000-2014

Year	Public spending in current Gh₵ million
2000	5.65
2001	7.34
2002	9.04
2003	15.43
2004	18.66
2005	21.27
2006	28.31
2007	36.75
2008	53.72
2009	80.36
2010	86.58
2011	97.22
2012	101.76
2013	153.93
2014	179.16

Source: Agriculture Public expenditure in Ghana, MoFA

Figure 4 presents trends in agricultural research spending intensity. The evidence indicates that agricultural research intensity (ARI) measured as public spending on agricultural R&D as a share of agricultural GDP in Ghana has consistently been less than the recommended 1% for developing countries, peaking at 0.71% in 2009. Comparing to other countries in the sub-region, Ghana's spending on the average is less than that of Senegal (1.15%), South Africa (0.87%) but doing better than Cote D'Ivoire (see Figure 4) (UNCTAD, 2011; Beintema et al., 2016).

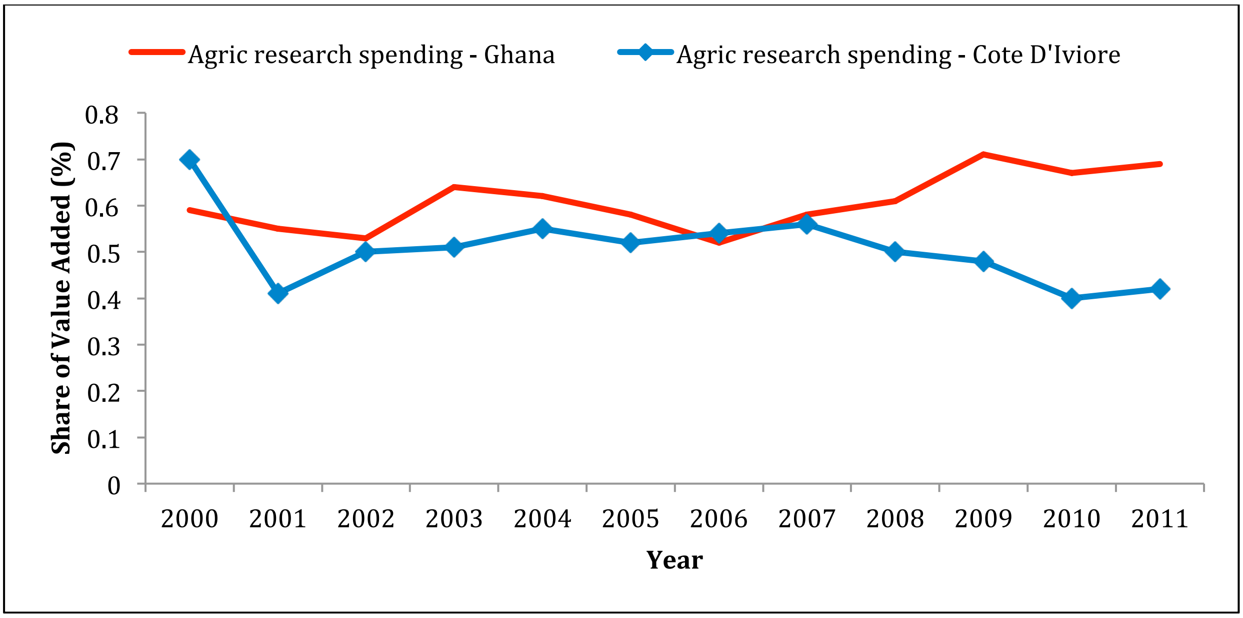

Figure 4: Trends in agricultural research intensity ratio, 2000-2011 Source: FAOSTAT, 2016

3.2 Human resource capacity

Agricultural innovation, whether within institutions, between the institutions, among entrepreneurs or farmers, in clusters or in agricultural innovation systems, mainly involves the interaction between actors who are people. Thus, the fundamental element of an innovation system is the individual innovators. Although the processes of innovation are influenced by, involved and have consequences for gender, the gender dimension is not highlighted in this paper due to data and time constraints.

3.2.1 Agricultural researchers (Full-time equivalents–FTEs)

The number of agricultural researchers declined from 469.6 FTEs in 2000 to 409.8 FTEs in 2002 and then increased consistently from 2003 growing at 4.5% annually peaking at 607 FTEs in 2011 (Figure 5). In general there has been an overall increase in research capacity in terms of FTE for the period under study. The increase in total number of agricultural researchers is found to be strongest at Ghana's public universities (Beintema et al., 2016).

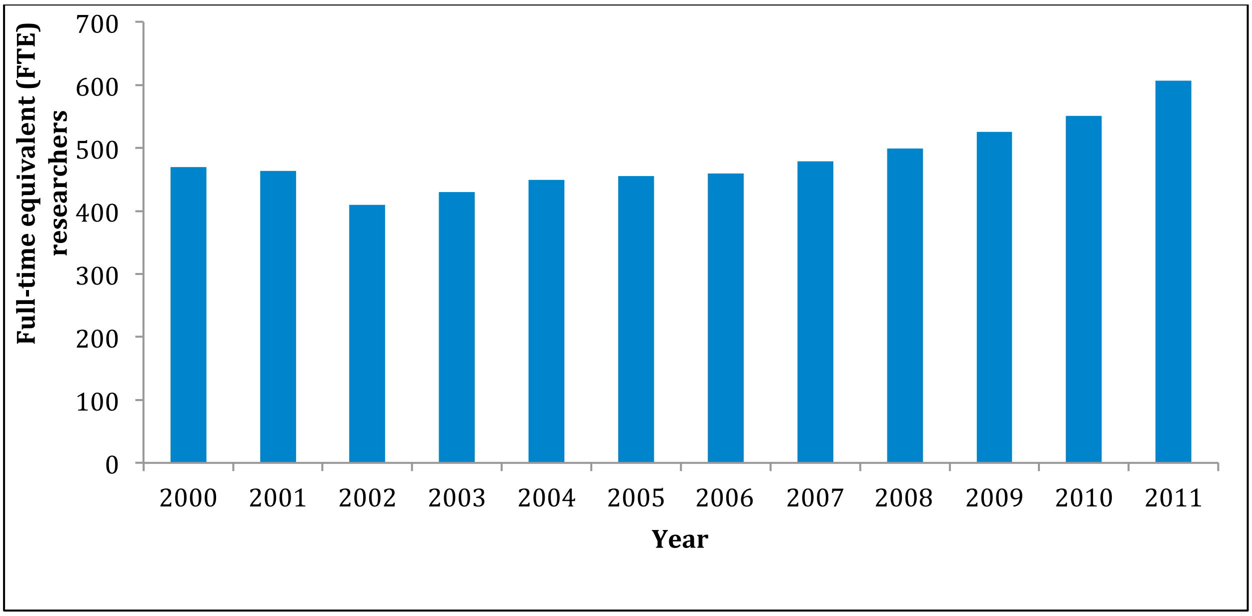

Figure 5: Public agricultural researchers, 2000-2011
Source: FAOSTAT, 2016

3.2.2 Agricultural researchers in Knowledge Institutions

Figure 6 presents the shares of researchers with MSc and PhD degrees in PRIs. Innovation R&D requires a high level of specialization. However, the number of researchers with PhD qualification is low in the PRIs, a situation which is worsened by the departure of about 42 qualified PhD researchers in 4 years (i.e. 2008-2012). What is worrisome is that about 60% of the current PhD researchers are either 50 years old or above (Essegbey et al., 2014). This means in the next few years or after 2022 this highly qualified research scientists will go on compulsory retirement: hence capacity gap will be created. Therefore prioritizing the training of experts at the PhD-level in the years ahead to fill existing and anticipated human resource capacity gaps is underscored. Meanwhile the quality of research staff in terms of composition of staff with MSc and PhD degrees among the population of researchers is higher for Ghana (95%) as against other African countries like Kenya (80%) but falls short of that in Cote D'Ivoire (99%) and Senegal (100%) (Beintema et al., 2016).

The current staff development policy which has taken effect in public universities and also in public institutions enables researchers with MSc degrees to upgrade and this has led to an increase in the number of researchers with PhD in recent times. For instance, the paid study leave system acts as an incentive for research staff to pursue further training opportunities, and this can help close staffing gaps and ensure sustainability.

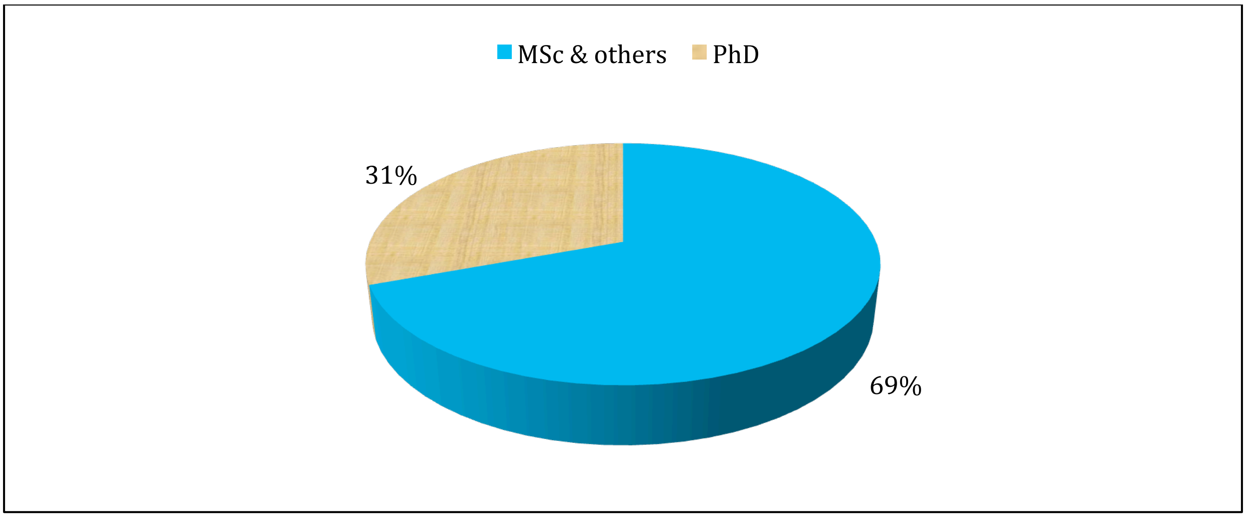

Figure 6: Agricultural researchers in public research institutions by qualification (in %)
Source: UNCTAD, 2011

The agricultural faculties of public universities in Ghana actively conduct agricultural R&D activities. The four (4) main public universities with such mandate include the UG, KNUST, UCC and UDS with 66 FTEs, 41 FTEs, 27 FTEs and 28 FTEs respectively, shown in Figure 7. One would have thought that KNUST which is much into STI activities would have more researchers compared to UG which is more into the classicals. But KNUST accounting for 25.3% of the total number of agricultural researchers in the country follows after UG (40.7%).

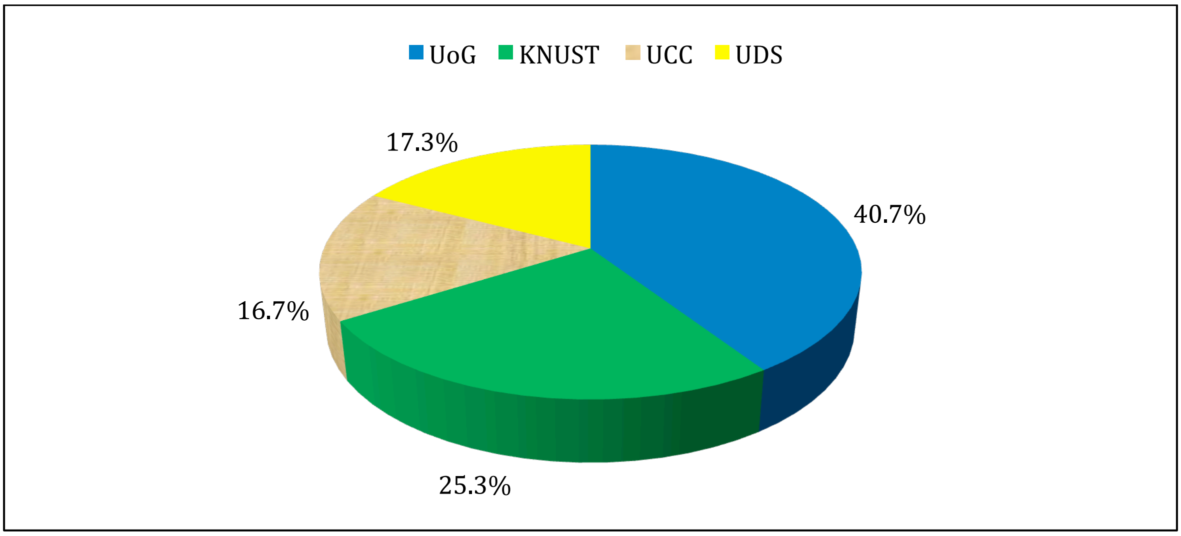

Figure 7: Composition of public universities' agricultural researchers, (in %)
Source: Essegbey et al., 2014

3.2.3 Trends in students pursuing higher degrees in the sciences

A positive development observed since the beginning of 2011/2012 academic year is a significant increase in enrolment of the total number of students pursuing masters and PhD degrees in the STEM institutions which are considered pipeline to innovations, Figure 8. The growth in masters and doctoral students' enrolment for 2011/2012 to 2012/2013 stood at 34.2% and 35.1% respectively compared to the abysmal performance of -0.1% (masters) and 0.3% (PhD) in 2010/2011 – 2011/2012.

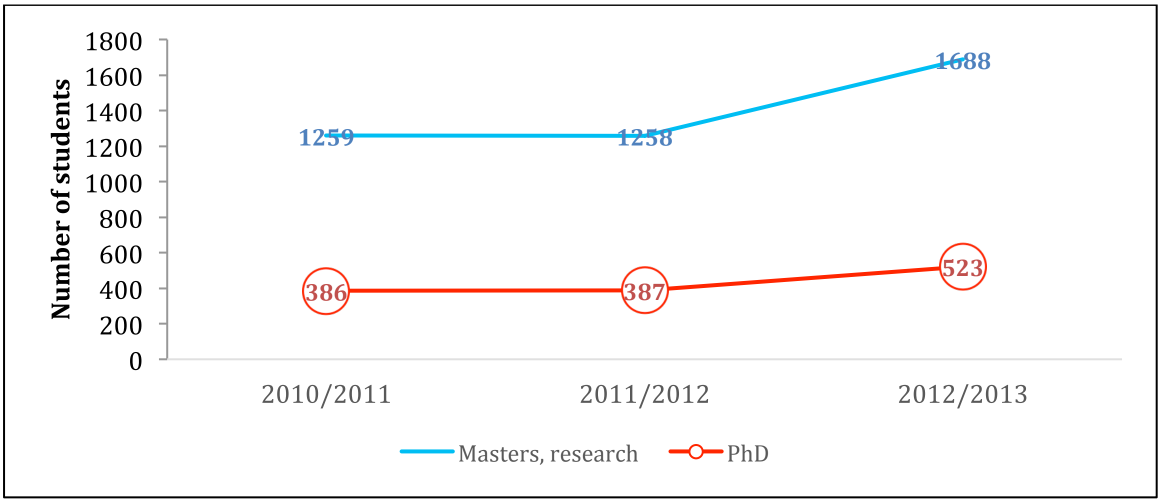

Figure 8: Trends in students pursuing masters and PhD in the sciences
Source: NAB, 2015

An area of great concern is the inadequacy and failure by government to develop the capacity of universities to educate and train more scientist and technologists up to the PhD level (MEST, 2010). Once this hurdle is overcome the universities that develop scientific and technological human resource would have the capacity to even do more and to conduct appropriate innovations research.

3.3 Performance of agriculture against growth targets

Doing performance analysis in reference to the 6% benchmark set by CAADP, it can be concluded that the impressive growth rates of 7.4%, 7.2% recorded in 2008 and 2009 respectively could not be sustained to achieve the annual target of 6% for the other years, Figure 9. In especially 2007 and 2011 the agricultural sector grew rather abysmally. What does the figure tell us? It means there are other factors which we have to work on. Increasing spending alone on agriculture is not enough except it is strategic. Spending must be purposeful to reduce dependence of agriculture on external and internal factors such as rainfall, other weather vagaries, fluctuations in world prices and so on. It must focus on on-farm productivity enhancements such as investment in R&D, irrigation, infrastructure, etc which will elicit the desired growth of the sector.

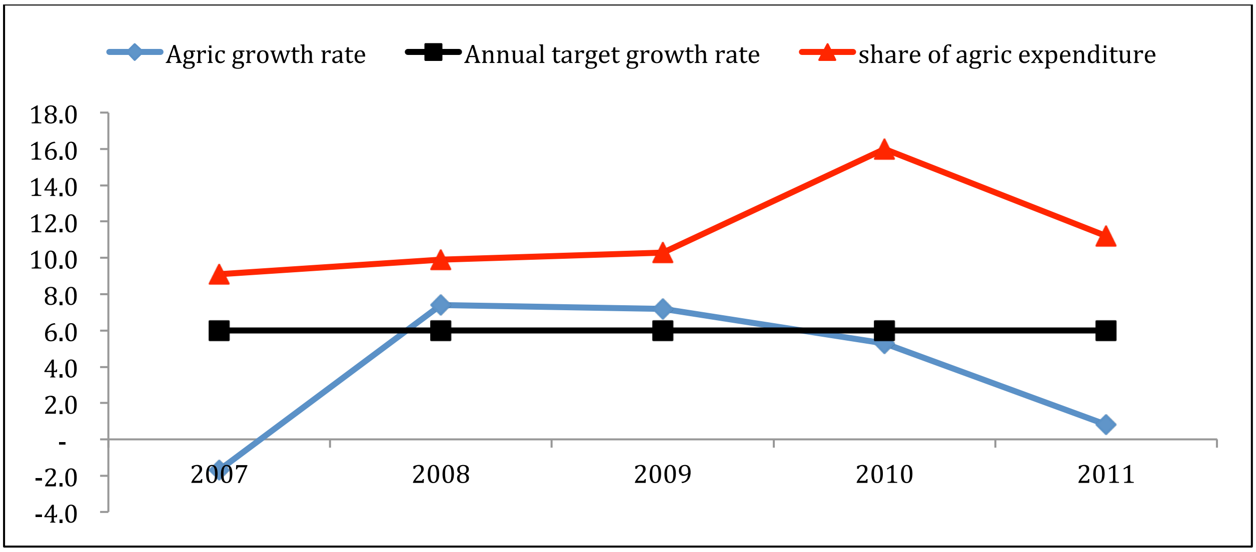

Figure 9: Agricultural growth rate against targeted growth rate, 2007 - 2011 Source: GSS, 2015 & MoFA/FASDEP, 2007

Where is the growth in productivity coming from?
The agricultural sector is dominated by the crops and cocoa subsectors which drive more than 50% of the growth of agricultural GDP. Growth in crops output which translates into growth of agriculture emanates from two sources: area expansion and/or productivity increase. Which of them accounts for output, subsector and agricultural growths recorded over the years? We note that data limitations could not allow us to consider the livestock, fisheries and forestry sub-sectors in the computations. In identifying the sources of growth in agricultural commodities which drive agricultural sector growth, we compute the percentage contribution of area (ha) and yield (t/ha) to observed production of each crop between 2004/2006 and 2011/2013 at the national level, using the following equations:

$$Area(\%) = \frac{[\log(Area2011/2013) - \log(Area2004/2006)]}{[\log(Prod2011/2013) - \log(Prod2004/2006)]} \times 100 \ldots\ldots\ldots\ldots\ldots(1)$$

This implies $Yield(\%) = 100 - Area(\%)$. Therefore,

$$Yield(\%) = 100 - \left\{ \frac{[\log(Area2011/2013) - \log(Area2004/2006)]}{[\log(Prod2011/2013) - \log(Prod2004/2006)]} \times 100 \right\} \ldots..(2)$$

Table 4 presents the results of the percent contribution of area and yield to observed output of crops. The results show that area expansion contributes more to the agricultural growth trends while productivity increase contributes less for rice, maize, sorghum and plantain. However, growth in production due to productivity increase is observed in cassava, yam and cocoa. Area expansion accounts for 100% of the growth in cocoyam output because in Ghana little or no attention is given to the development of this crop as it sprouts following the rains after field preparation. The forgoing results raise the question whether Ghana is "underinvesting" in on-farm productivity enhancing activities? These results provide evidence to support calls and recommendations by scientists to close the yield gap through R&D

tailored at developing innovations and effective extension service that connects innovators/innovations and farmers. This way the untapped potential in agriculture will yield maximum benefits to stakeholders in the agricultural sector.

Table 4: Contribution of area and yield to observed output of selected crops between 2004/2006 and 2011/2013

	Rice	Maize	Millet	Sorghum	Cassava	Yam	Cocoyam	Plantain	Cocoa
Area (%)	68.8	72.3	-215.1	288.2	28.61	24.3	100.0	51.5	-57.3
Yield (%)	31.2	27.7	315.1	-188.2	71.39	75.7	0.0	48.5	157.3

Source: Computed from MoFA/SRID, 2009 and 2013 data.

4.0 Conclusions

4.1 Agricultural research spending

- Innovation financing is weak in the country
- Share of agriculture in public budget has improved over the years with steady increase during the last decade under consideration.
- Agric research spending has improved as well but less than 1% of AgGDP.
- However the research budget of Ghana is tilted in favour of emoluments at the expense of investment which is considered critical to innovation development (World Bank, 2013).

4.2 Human resource capacity

- Despite growth in FTE researchers in Ghana, the number of qualified scientist and technologists in research institutions is quite “low.”
- Anticipated capacity gaps will be created, if not addressed, in the near future due to old age which will exacerbate the existing capacity gaps.
- However, the good news is that there has been a significant growth in masters and doctoral students’ enrolment since 2011.

5.0 Recommendations

5.1 Agricultural research spending

We recommend that:

- Government should be more committed to spending more on agriculture if indeed it wants to accelerate growth to achieve MGD now SDGs
- Ghana’s R&D investment should focus more on on-farm productivity enhancement activities
- Research institutions should diversify their sources of funds, particularly looking at the private sector for options such as producer

export levies on export or commercial crops, commercialisation of research outputs by partnering with private sector, etc.

5.2 Human Resource capacity

Here we state:

- The need to increase the capacity of universities to train more qualified scientists, technologists and innovators to fill existing and anticipated gaps in order to sustain the innovation momentum
- This should be complemented by emphasis on motivation of staff and recognition of outstanding scientists and technologist.

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ACHIEVING SUSTAINABLE IMPACT FROM DEVELOPMENT PROJECTS THROUGH MULTISTAKEHOLDERS INNOVATION PLATFORMS: LESSONS FROM GHANA AND RWANDA

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Abstract

Since decades, problems repetitively faced by development projects/programmes in developing African countries are known to be among others:

- Short-term (5–10 years) projects based interventions often built on hardly accurate diagnoses and planning;
- often partial implementation of planned activities of projects due to ill diagnoses and planning, poor implementation competences, and poor commitment of stakeholders to effectiveness; and,
- partial and sometimes biased monitoring and evaluation of projects, also due to ill diagnoses and planning, poor monitoring and evaluation (M&E) competences, and mostly poor commitment of stakeholders to the implementation of relevant M&E approaches.

However, up to date, development projects designers and supporters seem hardly interested in seriously addressing these key problems, and continue designing, financing, implementing, monitoring and evaluating projects almost following same approaches.

This paper calls attention of decision makers on the need to stop supporting ill design implementation, monitoring and evaluation of projects, and to innovate by enhancing the chance for target developments to effectively occur. It argues that competent and committed multistakeholders' platform approach to development projects can improve the potential for effectiveness of the projects and the measurement of their effects on target people.

Keywords: Development projects and programmes; effective management; Innovation; multistakeholders' platforms.

Introduction

Contributing to the improvement of livelihoods of poor rural people remains the main objective pursued by most development projects/programmes to date. However, it remains also obvious that projects that reach effectively this target are rare (IFAD, 2011; Chen &Ravallion, 2013; Hermano *et al.*, 2013; Olinto *et al.,* 2013). Meanwhile, succeeding with improving the livelihoods of as many poor people as possible may reduce the population of poor people and improve the overall well-being and security of target projects' areas, countries, and the world (IFAD, 2011).

This paper aims at quickly recalling to readers, intervention approaches used by most development projects to date, and discusses the potential of multistakeholders' innovation platforms (IP)' approach in the improvement of effectiveness of development projects. It case studies few IP mediated development projects and will argue that building intervention on multistakeholders innovation platforms may be worth considering to guarantee more effectiveness and effects from development projects. We expect this paper to add to debates on effectiveness of development projects, and to help financial and technical partners to improve on their impact on development of funded countries.

Literature

The subject of effectiveness of development projects has been intensively addressed in the literature (Hermano *et al.*, 2013; Kouévi *et al.*, 2011; Kouévi, 2013), among other things, in terms of critical success factors to consider for more success of international development projects. Main critical success factors identified and discussed to date are: schedules management, budgets management, stakeholders/clients satisfactions, quality of project management processes, monitoring and feedback, top management support, and quality management. To address those factors, some alternative project management frameworks have been proposed, such as –project management body of knowledge (PMBOK), international project management association competence baselines (ICB), results frameworks (RF), and project management for development professionals (PMD Pro 1) (Hermano *et al.*, 2013). These frameworks have been proposed to correct success shortcomings of the logical framework approach (LFA) still in use by some international development projects and donors for projects' design, implementation, monitoring and evaluations. However, to date, effects of these alternative frameworks on the effectiveness of development projects are not yet neatly established. This paper discusses the effectiveness of multistakeholders innovation platforms' mediated projects in order to provide development project actors with information on the potential effects they can reach through such platforms.

Key concepts

Key concepts used along this paper are: development projects, effectiveness, accuracy, transparency, institutionalisation, commitment, innovation, and innovation platform.

By *development projects or programmes*, we mean all financial and time resources bound (one to five, ten, or more or less years) initiatives aimed at improving livelihoods of target people. Development projects follow many iterative steps to get realised – idea/s, diagnosis, re/design and re/planning, fund raising, implementation, monitoring and evaluation, etc.

Success or effectiveness of projects depends on the seriousness of attentions given to each of project steps. Effectiveness in this paper is meant to state that planned activities are implemented and expected outputs and outcomes are reached. This means that a project can be said to be effective only and only when it reaches expected outputs and outcomes. Contingencies can prevent projects from being hundred percent effective, however, we will argue in this paper that many measures may be truly taken along steps of projects design and implementation such as to make sure that projects are effective at a rate far beyond fifty percent.

Accuracy is addressed in this paper in terms of unambiguous precisions about activities, locations of activities, target people, time horizons, target outputs, target outcomes, performance/effectiveness and job promotion criteria. Such precisions must be clearly mentioned in projects' documents, also for accuracy purposes.

By *transparency*, we mean open accessibility of project documents, decisions, and information on activities, outputs and outcomes to all stakeholders.

Institutionalisation means the establishment of rules to be followed by all interdependent and engaged stakeholders.

Application of rules or concern for the respect of rules, can commit interdependent stakeholders to the effective respect of rules. This is why the concept of *commitment* is used in this paper, to point to the concern of people for the fulfilment of agreed decisions.

Here, *innovation* is meant for all measures taken or proposed for the improvement of effectiveness of development projects.

Multistakeholders Innovation Platforms are physical, virtual and/or physico-virtual fora or networks through which, interdependent stakeholders iteratively interact, communicate, share resources, and deliberate for mutual benefits around overlapping issues or interests (Adekunle *et al.*, 2013; Boogaard *et al.*, 2013).

Methodological framework

To explore reasons behind the failure of livelihood improvement projects in rural areas in Africa, we case studied three functional agricultural innovation platforms (IPs), and three not well functioning IPs in Ghana (West-Africa) and Rwanda (East-Africa) (see table 1 in result section). We targeted platforms of these two African countries because we considered that they both provide us with success stories that can allow learning about reasons for failure and success of IP mediated projects. In each of the IPs, we interviewed at least one stakeholder from each category of stakeholders. Categories of stakeholders we could interview in the platforms were – farmers, processors, transporters, marketers, input suppliers, platform facilitators, extension officers, local administration officers and policy-makers, and researchers. Discussions with these stakeholders allowed us to learn about their appreciations of, and their suggestions for, the functioning of IPs. The commodity value chains addressed by the platforms studied were – citrus, cassava, cow milk, potato, pepper, tree tomato, beans rich in iron, and passion fruit. Data collected from the stakeholders were – name of IP, time of creation, location, initiation process, reasons for creation, activities implemented, state of affairs, reasons for (dis)continuation of functioning, and challenges.

Data are analysed building on interpretive comparison between characteristics, experiences, and functioning status of innovation platforms (IPs) and innovation platforms for technology adoption (IPTAs). Analyses focus essentially on functioning statuses (state of affairs), reasons for (dis)continuation of functioning, and challenges, for the inference of reasons for failures and success of IP mediated projects.

Results and discussions

This section presents and discusses the research results. Table 1 describes case studies as follow:

Table 1: Case studies and findings

Coun-tries	Case studies	Descriptions
Ghana	Kwaebibirem Citrus IP	**Location**: Kwaebibirem district, Eastern region; **Time of creation**: February 2015; **Initiation**: Design and submission of proposal by researchers from Citrus researchers of University of Ghana to the Platform for African European Partnership on Agricultural Research for Development [PAEPARD] for fund raising; **Reasons for creation**: Find solutions to citrus diseases and pest problems. **Activities implemented**: Joint discussion of citrus production and marketing issues; search for some solutions by researchers, and joint search for solutions for other common issues; and implementation of defined solutions. Spraying gang of 5 members trained to spray citrus farms of citrus farmers of the district. **State of affairs:** Funding from PAEPARD ended, however the IP is still functional; **Reasons for continuation of functioning**: Platform still meeting stakeholders needs and interests for interaction (spraying service gang at reasonable cost [around 5 to 10 Ghana Cedis for the treatment of one acre of citrus farm, pesticides' cost non included], Information and communication still active via phone calls, sms, and whatsapp, Dissemination of technology still active, Market linkages and negotiation of profit still going on); **Challenge:** Funding for continuation of research activities is no longer from first donor but other sources.

	UrumpoGyenyame Cassava Farmers and Processing Group	**Location**: Urumpo community, Wenchi district, Brong Ahafo region; **Time of creation**: Around June 2011; **Initiation**: Crop researchers of Crop Research Institute of Kumasi (Dissemination of New Agricultural Technologies in Africa [DONATA project]); **Reasons for creation**: Finding and adopting productive cassava varieties, improving cassava weeds control, production, and processing skills of farmers; **Activities implemented**: Joint discussion of cassava production, processing, and marketing issues; joint definition of solutions; distribution of responsibilities among partners; trainings; joint experimentation and learning; and joint monitoring and evaluation of experiences; **State of affairs:** Funding from DONATA ended, and no more activity of the IPTA; **Reasons for non-continuation of functioning**: Platform not meeting stakeholders needs and interests for networking (stakeholders use to rely essentially on funds and ideas from financial and technical partners for any initiative); **Challenge:** Raise interests of stakeholders for networking for mutual benefits.
	Wenchi Cassava innovation platform for technology adoption (IPTA)	**Location**: Wenchi community, Wenchi district, BrongAhafo region; **Time of creation**: 2012; **Initiation**: Crop researchers of Crop Research Institute of Kumasi (DONATA project); **Reasons for creation**: Finding and adopting productive cassava varieties, improving cassava weeds control and production skills of farmers.; **Activities implemented**: Joint discussion of cassava production, processing, and marketing issues; joint solutions defining; distribution of responsibilities among partners; trainings; joint experimentation and learning; and joint monitoring and evaluation of experiences.; **State of affairs:** Funding from DONATA ended, and no more activity of the IPTA; **Reasons for non-continuation of functioning**: Platform not meeting stakeholders needs and interests for networking (stakeholders use to rely essentially on funds and ideas from financial and technical partners for any initiative); **Challenge:** Raise interests of stakeholders for networking for mutual benefits.
	NyameBekyere farmers association of Ayigbe	**Location**: Ayigbe community, Wenchi district; **Time of creation**: June 2011; **Initiation**: Crop researchers of Crop Research Institute of Kumasi (DONATA project); **Reasons for creation**: Finding and adopting productive cassava varieties, improving cassava weeds control and production skills of farmers.; **Activities implemented**: Joint discussion of cassava production, processing, and marketing issues; joint solutions defining; distribution of responsibilities among partners; joint experimentation and learning; and joint monitoring and evaluation of experiences. Payment of dues; Social supports (funerals, sickness, loans, etc.); *Nobua*(mutual farming help).**State of affairs:** Funding from DONATA ended, however the IPTA is still functional; **Reasons for continuation of functioning**: Platform still meeting stakeholders needs and interests for networking (a functional unit for cassava processing into *Gari* has been created and is used by all stakeholders for profit making; entrenchment of commercial activities around the *Gari* value chain; still strong interests of stakeholders for networking for mutual benefits); **Challenge:** Maintain linkage with extensionists, and any other useful technical and financial partners for technical and financial supports.
Rwanda	Cow milk and Irish potato IP Huguka Mudende	**Location**: Mudende Sector, Rubavu district, Northern Province; **Time of creation**: 2008; **Initiation**: Sub-Saharan Africa Challenge Programme (SSACP) funded by the forum for agricultural research in Africa (FARA); followed by supports from government, and other partners; **Reasons for creation**: Proof of integrated agricultural research for development (IAR4D) concept of FARA. Main issue addressed: organise milk sale value-chain such as to allow local milk sellers to earn more money; **Activities implemented**: Purchase of milk from local people, conservation of milk collected, resale of the milk collected; Potato varieties and seeds multiplication in green house; potato seeds supply to IP members; potato production by IP members and sales to clients; joint monitoring and evaluation of farming activities of seeds beneficiaries, and of milk sales; **State of affairs:** Funding from SSACP ended, however the IP is still functional; **Reasons for continuation of functioning**: Platform still meeting stakeholders needs and interests for networking (IP continues collecting cow milk from all suppliers and commercialising at profitable prices), and more financial and technical partners supporting the platform; **Challenge:** Maintain linkage with

	extensionists, and any other useful technical and financial partners for technical and financial supports.
Pepper, Beans rich in Iron, Passion fruit, Tree tomato, and livestock IP of Rwerere	**Location**: Rwerere sector, Musanze District, Northern Province; **Time of creation**: December 2008; **Initiation**: Sub-Saharan Africa Challenge Programme (SSACP) funded by FARA; **Reasons for creation**: Proof of IAR4D concept of FARA. Main problem addressed: Soil erosion, marketable crop profitable for soil conservation; **Activities implemented**: Joint discussion of production and marketing of yellow pepper, Beans, passion fruit, japan fruit, and livestock; joint solutions defining; distribution of responsibilities among partners; joint experimentation and learning; and joint monitoring and evaluation of experiences; **State of affairs:** Funding from SSACP ended, and the IP is struggling to remain functional; **Reasons for slow continuation of functioning**: Stakeholders still believe that they can gain from the platform, despite they failed with marketing the yellow pepper they started with (diversification of value chains from pepper to others; technical support relationships maintained with some partners; seeking of more financial, technical and marketing partners); **Challenge:** Linking up with market opportunities.

Source: Our survey in Ghana and Rwanda, May 2015 to March 2016

From analyses of the contents of table 1, one can read that – Kwaebibirem Citrus IP (Ghana), Ayigbe IPTA (Ghana), IP Huguka Mudende (Rwanda), and IP of Rwerere (Rwanda), are innovation platforms with sustainability potentials (see state of affairs), because they remained functional despite their initial sources of funds ended. Meanwhile, Urumpo IPTA (Ghana), and Wenchi IPTA (Ghana) are platforms with little potential for sustainability, because of their apparently over reliance on external financial and technical supports, and their poor contribution to the fulfilment of interests of their stakeholders. Comparing both categories of platforms (with and without sustainability potentials), we can also notice that exhaustiveness in addressing commodity value chains (from production to marketing), and internal funding and fund raising mechanisms are key for effectiveness and sustainability potential of IPs, because they contribute to raising and maintaining interests of stakeholders in platform activities. Especially, money earning by stakeholders or money-earning related supports constitute the main drivers for the continuing functioning of innovation platforms. The Ayigbe IPTA (with sustainability potential) for instance could benefit from both financial and technical supports of DONATA project both for the production of cassava up to the processing of cassava into *gari*, and to the marketing of *gari*. Especially, the platform could establish a unit for cassava processing into *gari* with management rules that can potentially allow the unit to function for relatively long term. Apart from the financial support from DONATA, the Ayigbe IP members used to save money among themselves for mutual social supports, and therefore to feel interdependent. These quite exhaustive internal and external supports to the functioning of the Ayigbe IPTA justify its sustainability potential.

The same reasoning applies to the potentially sustainable IP of Mudende (Rwanda) that benefits from the financial and technical supports from different partners, as well as allowing its stakeholders to earn more money from the collection, storage-conservation, and marketing of fresh cow milk.

This IP allows also its members to access clean Irish potato seeds and to produce, sell, and gain revenues from potatoes.

Meanwhile, despite Urumpo and Wenchi IPTAs also benefited from the financial and technical supports from DONATA project as the Ayigbe IPTA, they were not able to continue functioning at the end of the DONATA project, perhaps because, among others, the commodity value chains were not relevantly chosen, or because the supports they received were not enough sufficient to allow them to sustain themselves without further intensive supports. Further analyses of the functioning of these two IPTAs show that compared to the Ayigbe and Mudende platforms, not only they do not gain yet any revenue from their cassava value chains, but also they do not have any internal fund raising mechanism. In the end, because of little chance for making revenue from the IPTA, stakeholders hardly participate in the platform's activities, hence the little chance for the platform to perform and sustain itself.

As for the citrus IP, it continues functioning because of the relatively strong advisory, feedback, and marketing linkages established among farmers, researchers, extension workers, input suppliers, processors, local administration officers, NGOs, etc., via physical meetings, mobile phone calls, SMS and whatsapp messaging and calls. Here, the diversity of stakeholders and the level of interdependency among stakeholders seem to play a big role in the continuation of the platform activities. Researchers get research subjects and information from all the other stakeholders that they advise whenever needed. Input suppliers advertise for their products, and they direct clients to nearby input shops. Processors advertise for their availability to buy citrus fruits from farmers, and participate in advising farmers and input suppliers on the quality of citrus they like, etc. Farmers kindly request specific advice. Extension workers take advantage on the platform to advise farmers, and alert them for timely implementation of farming activities, etc. In all, the citrus IP looks and functions as a perfect platform whereby, stakeholders are diverse, feel interdependent, and support each other for mutual benefit.

Rwerere IP is a platform which continues functioning somehow, based on the concern of the stakeholders for its functioning. Indeed this IP has been created almost at the same time as Mudende IP in 2008 under the same project (SSA-CP), and the Rwerere IP stakeholders are aware of the potential benefits they can gain from a functional IP. Therefore, after they have failed selling the yellow peppers with which they started the platform, they have started exploring other promising commodity value chains. Beans rich in iron seems for this platform a promising commodity value chain, however, it continues seeking technical support for the production and the marketing of this crop. This commitment to success from the platform facilitators and stakeholders raises hope that Rwerere IP can become fully functional with sustainability potential.

Conclusion and policy recommendations

This paper studied the functioning of six agricultural innovation platforms from Ghana and Rwanda to identify conditions conducive to effectiveness of development projects. Among these six platforms, three functions with high effectiveness and sustainability potentials, while the other three function with little effectiveness and sustainability potential. Analyses revealed that the platforms functioning with high sustainability potential have internal (financial and in-kind contributions from stakeholders), and external fund raising mechanisms, address all commodity value chain issues (from production to marketing), address issues/interests (value chain information, and income generation needs) of their stakeholders, and make stakeholders feel interdependent and committed to the functioning/effectiveness of their platform.

Advantages of intervening through innovation platform are that – interventions are focused (target people are well known and localised); participation of all target people, information and communication around intervention activities, and accuracy of interventions are highly possible; monitoring and evaluation have the potential of being participatory, accurate, and accountable; and effects of interventions are accurately measurable. Given all these potentials of innovation platforms for committing stakeholders to effectiveness, building development projects around such kind of platforms may enhance the chance of effectiveness and effects of the concerned projects. Thus, this paper recommends that further development projects innovate by building their activities around IPs.

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THE NEXUS OF INNOVATION AND ENTREPRENEURSHIP – A CASE STUDY OF THE ALPHA MUSHROOM CLUSTER

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Abstract

Alpha Mushroom cluster is one of the clusters that was nurtured by the CSIR – STEPRI as part of activateis of the Pan African Competitiveness Forum (PACF) in February 2010. The cluster is hosted by the Ghana Chapter of the Pan African Competitiveness Forum with support from the Swedish International Development Cooperation Agency (SIDA). Alpha Mushroom Cluster is now a full-blown association having been registered at the Registrar Generals Department as an association with their own board of executives to organise activities for its members and affiliates.

The association, has had its fair share of challenges, but with the support it continues to receive from CSIR-STEPRI, has been able to overcome these challenges and chalked some few successes along the line that are worth noting. These successes are the successful development of some mushroom products such as mushroom bread, mushroom khebabs, mushroom chips, mushroom wine, canned mushrooms, mushroom shito (pepper sauce), dried mushrooms, and the mushroom powder to mention a few. This has been possible due to the drive of innovation and entrepreneurship which has been infused into training programmes provided by CSIR-STEPRI to the association.

In as much as there has been successes achieved, there are still some problems that the association faces which requires the assistance of the government, its ministries and agencies as well as other NGO's to be able to meet the aims and objectives and to develop the cluster into a formidable tool for national development. They include money and motivation, marketing, machinery and equipment, and education and awareness creation. The association requires assistance in these areas to be able to make significant impacts in job creation, improve incomes and livelihoods.

Introduction

Nexus, Innovation and Entrepreneurship

According to the Oxford Living Dictionaries Online, a *'nexus'* is *"A connection or series of connections linking two or more things"* or *"A central or focal point"*. Without bothering to explain "innovation" and "entrepreneurship" as we are in the midst of academics and the intelligentsia there would however, be the need to explain the term "nexus" as it is not a word in everyday use. In this presentation therefore, we will attempt to identify the connection between "innovation" and "entrepreneurship" using the Alpha Mushroom Cluster as a case study. We will also consider how "innovation" could be the central or focal point for the development of the Mushroom industry in Ghana presently and how it could be used in the future to transform the economy by creating jobs, alleviating poverty and improving the health and well being of the Ghanaian populace and the nation as a whole, from the cultivation and consumption of mushrooms.

Why the need for Innovation in Ghana

When I begun to research on this topic before writing it, I came across a course on the internet titled *"The Foundation of Innovation and Entrepreneurship in China"* I found it quite interesting that there was a course like that and it moreover, was being offered for free through FutureLearn, a distance learning online education company owned by The Open University. I contemplated whether I should take advantage to learn something more about the topic from this five week course, but decided against it initially because I thought it was about China, whilst I was expected to talk about Innovation and Entrepreneurship in Ghana. But upon further reflection and thinking about it, I realized that much as it was about China, there could be some insights to be gleaned from the course which could apply to Ghana, so I finally decided to take the course, and moreso because it was for free, I believed I could definitely learn a thing or two from it. I really did learn a thing or two, right from the very beginning of the course: about why innovation was very important and actually very urgent for the development of entrepreneurship in Ghana, much as it was for China, and I would like to share my thoughts on what I learnt on the very first day of beginning this course and how it relates to Innovation in the Ghanaian context.

I learnt that although the Chinese economy has the second largest economy after the US, in the past few years the Chinese economy has slowed down and has experienced massive pressures. This is because that economy had been mainly based on a low-cost strategy over the past few decades, but this low-cost model has been recognized as not been sustainable. Chinese goods used to be the cheapest, no matter which part of the world it was imported to, especially for goods that are imported to Africa. We are all aware of how much goods produced from China are very cheap and sometimes inferior in quality, compared to our own locally produced goods. Presently, labour, material and land costs have all increased dramatically in China and it is quite clear that the Chinese economy is presently facing difficulties although they are considered middle-income economically, with a GDP per capita income of $7,500 USD. According to the World Bank economic classification the middle-income stage is when a country has a GDP per capita of between $3,000 - $9,000 USD like China. Likewise countries with a GDP per capita income of $1,026 to $4,035 USD like Ghana, at the moment with a GDP per capita income of $1,695.08 USD are at the lower-middle-income stage. China wants to move forward into the high-income stage where the GDP per capita should be upwards of more than $17,000, instead of being stuck in what the World

Bank calls "The middle-income trap" How can this problem be solved and how can Ghana like China seeks to do, move from the lower-middle-income level of growth into the middle-income stage? Are there some lessons that we can learn from China as they work hard to follow the prescription of the World Economic Forum? The World Economic Forum (WEF) has prescribed the recipe for rising to the high-income stage for Ghana as well as for other countries. That prescription is innovation. Innovation is the driving force for the Chinese economy and the main candidate to lead them out of the middle-income stage to ascend unto the high-income level of industrial growth and economic development. And it is the same for Ghana if we take a good look at our Innovation capability and take the right steps to move our economy from its present lower-middle-income to the middle income level.

The Global Innovation Index and Ghana's Innovation Capability

The Global Innovation Index (GII) an organization that ranks countries' Innovation Capability every year, aims to capture the multi-dimensional facets of innovation and provide the tools that can assist in tailoring policies to promote long-term output growth, improved productivity, and job growth. The GII helps to create an environment in which innovation factors are continually evaluated. It provides a key tool and a rich database of detailed metrics for economies, which in 2016 encompassed 128 economies, representing 92.8% of the world's population and 97.9% of global GDP.

The Global Innovation Index 2016 (GII), in its 9th edition this year, is co-published by Cornell University, INSEAD, and the World Intellectual Property Organization (WIPO), an agency of the United Nations. The core of the GII Report consists of a ranking of world economies' innovation capabilities and results. Over the last nine years, the GII has established itself as a leading reference on innovation. Understanding in more detail the human aspects behind innovation is essential for the design of policies that help promote economic development and richer innovation-prone environments locally. Recognizing the key role of innovation as a driver of economic growth and prosperity, and the need for a broad horizontal vision of innovation applicable to developed and emerging economies, the GII includes indicators that go beyond the traditional measures of innovation such as the level of research and development.

The GII in 2013 and 2014 ranked China 35th and 29th respectively, whilst Ghana was ranked 94th and 96th respectively. In the past 2 years of 2015 and 2016, China, using the WEF prescription of innovation as the driving force, maintained their 2014 position and in this year has inched closer to the top securing the 25th position; whereas Ghana in 2015 fell lower to the 108th position and managed to improve this year to attain the 102nd position on the Global Innovation Index. Even at their current position, China believes that it needs to improve, and its economists believe that there is the great need for innovation based entrepreneurship, instead of the low-cost based entrepreneurship that has been going on in the last 30 years. China is therefore working hard to transition from a low-cost strategy to an innovation-based strategy and that is why innovation and entrepreneurship are very frequently discussed in China now. Ghana in the same vein had been classified as a developing country for a long time since independence nearly 60 years ago and has only recently been 'promoted' into the class of lower-middle-income countries with a GDP per capita of $1695.08 USD in 2015, having been a mere producer of raw commodities for export such as our cocoa beans, our gold, timber and other natural resources, rather than processing them into semi-processed or finished goods for export.

I therefore hold the opinion that that this discussion on entrepreneurship should not just end here, but should be continued from this conference into our socio-political and scientific research discussions, back in our offices, our industrial establishments and factories and even amongst mushroom farmers and other crops and animal farmers like ourselves at the Alpha Mushroom Association. The mushroom farmers of the Alpha Mushroom Cluster through the support and assistance that we have always received from CSIR-STEPRI, believe that innovation is what leads to economic growth as a nation and will impact our industries, schools, and even our research institutions such as the CSIR. We have therefore in our own small way attempted to be innovative in developing our mushroom industry with value added products such as the mushroom bread, the mushroom wine, the mushroom shito (a form of pepper sauce), mushroom chips and the mouth-watering mushroom khebabs. Some of these products are being exhibited at this conference.

<u>The Development of the Mushroom Industry and the Alpha Mushroom Cluster</u>

Mushroom production in Ghana really started in the 1990s when a Ghanaian scientist, Leslie Sawyerr of blessed memory, son of Harry Sawyerr, also of blessed memory, a former member of the Council of State, former Minister of Transport and Communications, former Minister of Education and former Member of Parliament, introduced some interested people to the cultivation of oyster mushroom, which he learnt during his trips to Belgium and China (Galandzy, 2006).

In Ghana, mushrooms are well known and consumed in many households. In the countryside and forest regions, several species are collected for consumption. During the onset of the rainy season, when mushrooms are abundant, most people in rural areas collect them from the forests for home consumption and sell for extra income. The current rate of bush burning, deforestation and over-exploitation of timber and non-timber forest products, are greatly threatening the availability of mushrooms in Ghana. The introduction of the National Mushroom Development Project in 1990 (Sawyerr, 2000) to produce exotic mushrooms such as Pleurotus species brought about small scale mushroom farms mostly for the urban unemployed while technologies developed for the Straw mushroom, Volvariella volvacea, the most preferred, have not been adequately transferred to the rural communities for the improvement of their livelihood.

The 2nd Continental Conference of the Pan-African Competitiveness Forum (PACF) that led to the birth of Alpha Mushroom Cluster

The Alpha Mushroom Cluster begun in 2010 after one of the members of the Mushroom Growers and Exporters Association of Ghana (MUGREAG), Mrs. Constance Tengey attended the Pan African Competitiveness Forum (PACF) in February 2010 organised under the auspices of CSIR-STEPRI, hosted by the Ghana Chapter of the Pan African Competitiveness Forum with support from the Swedish International Development Cooperation Agency (SIDA).

The PACF as a new continental organization came into existence in April 2008 in Addis Ababa with the support of the African Union (AU) and SIDA in collaboration with The Competitiveness Institute (TCI). The establishment of the PACF was in response to the concern to see Africa develop in a sustainable manner and achieve the Millennium Development Goals within the foreseeable future, and get integrated into the global economy. African countries should not merely be producers of raw materials but exporters of value added products and services. The PACF's vision of Africa's integration and effective competition on the global stage is founded on innovation and cluster-based initiatives bringing government, academia and entrepreneurs into a triple helix partnership.

After the PACF conference in Elmina, MUGREAG, with assistance from STEPRI organised some of their members into a cluster now known as the Alpha Mushroom Cluster, which held and continues to hold their meetings within their premises. Through the continued assistance from STEPRI, Alpha Mushroom Cluster has continued to develop into a full blown association which has been registered at the Registrar Generals Department as an association having elected their own board of executives, governed by its own written constitution, some of whom are here delivering this paper today. Alpha Mushroom Cluster has also with sponsorship from STEPRI in collaboration with the CSIR - Forestry Research Institute (FORIG) received training into the cultivation of other species of mushroom such as the Volvariella volvecea or Oil Palm mushroom by Dr Mary Apetorgbor, which trained more than 100 members of the cluster on how to cultivate the Oil Palm mushroom species. For us to better understand how the Alpha Mushroom Cluster hopes to develop going forward, shall we look at the meaning, composition and characteristics of a cluster and what is expected of a cluster in its stages of development.

What is a cluster?

Organizations and scholars have developed several definitions of what a cluster is. In general, most theories agree that a cluster should be composed of organizations covering the "triple helix", within a geographical defined area. Professor Michael E. Porter offers the following definition of a cluster:

"A cluster is a geographical proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and externalities." (Michael E. Porter, On Competition. Harvard Business Press, 1998, p.215)

The cluster theory is based on the notion that clusters have certain characteristics, which contribute to enhance innovation, growth and competitiveness of regions and the companies which are part of clusters. However, some of the synergies within a cluster are latent, and in order to fulfill and exploit these synergies, a cluster initiative can be established.

"Cluster initiatives are organized efforts to increase the growth and competitiveness of a cluster within a region, involving cluster firms, government and/or the research community." (Örjan Sölvell, Göran Lindqvist and Christian Ketels, The Cluster Initiative Greenbook, Ivory Tower AB, 2003) A cluster initiative is led by a cluster organization, which initiates and strengthens joint activities among its members related to:

- **Increased innovation and technology capacity**
- Cluster networking and trust-building
- Human resources upgrading
- Expanding the scale and scope of the cluster
- Business development
- Business environment

Achievements and Innovative ideas that has been developed by the Alpha Mushroom Cluster

With the above expectations of a cluster and the activities that contribute to its development and the growth of its members' business and enterprises, we would like to situate the goals of the Alpha Mushroom Cluster as stated in the Aims and Objectives of our constitution as follows:

a) To see to the improvement of processing, diversification and the value addition chain in the mushroom business;
b) To help promote the skills and efficient training of individual farmers to enhance quality and expanded production in mushroom farming;
c) To seek and create more marketing centres for farmers;
d) To seek the general welfare of members and help members secure finance to ensure business promotion; and
e) To strengthen unity among members and cooperate with mushroom growers nationwide as a solid and AUTONOMOUS BODY.

From the above mentioned, it can be said that the Alpha Mushroom Cluster has been working hard to achieve these goals, particularly in the area of processing, diversification and adding value to the raw mushroom that has yielded the successful development of some products that have been listed below and can be inspected at our exhibition stand outside the conference hall.

1. Mushroom Bread
2. Mushroom khebabs
3. Mushroom Chips
4. Mushroom Wine
5. Canned Mushrooms
6. Mushroom Shito (pepper sauce)
7. Dried Mushrooms
8. Mushroom Powder

All of these products are at varied stages of development and a lot of assistance is required, from both governmental and non-governmental agencies for the improvement of these innovative products that have the potential to be developed into exportable items which would bring in the much needed foreign exchange for national and economic development. Assistance from government agencies such as the Ghana Standards Authority, the governmental agency responsible for the maintenance of acceptable standards for product and services, the Food and Drugs Authority, the government agency responsible for the inspection, certification and proper distribution of foods and food products, and the Ghana Export Promotion Authority (GEPA), the National Export Trade Support Institution of the Ministry of Trade and Industry (MOTI) responsible for the facilitation, development and promotion of Ghanaian exports.

We are requesting the assistance of non-governmental agencies and financial institutions such as the banks, financial NGOs to support our members businesses and to provide loans, grants and other financial assistance programs to enable our members to expand their production base and also produce mushrooms and mushroom products that would be a able to compete favorably with other mushroom products from anywhere in the world.

<u>What the Alpha Mushroom Cluster seeks to achieve</u>
Alpha Mushroom Cluster has 3 main areas where we hope to make significant impact: in the areas of job creation, poverty alleviation and improving the health of the nation.

Job Creation - Mushroom cultivation can help reduce vulnerability to poverty and strengthens livelihoods through the generation of a fast yielding and nutritious source of food and a reliable source of income. Since it does not require access to land, mushroom cultivation is a viable and attractive activity for both rural farmers and peri-urban dwellers. Small-scale growing does not include any significant capital investment: mushroom substrates can be prepared from any clean agricultural waste material, and mushrooms can be produced in temporary clean shelters. They can be cultivated on a part-time basis, and require little maintenance. Alpha Mushroom has been training its members and the general public, in collaboration with churches, institutions and other NGOs in Accra and other parts of the country on the cultivation as well as innovative ways of producing mushrooms and mushroom products.

Poverty alleviation - Mushroom cultivation can make a valuable contribution to sustainable livelihoods for both rural and urban poor, because they are highly compatible with other livelihood activities, requiring minimal physical and financial inputs and resources, to be undertaken successfully. Furthermore, it represents an ideal activity for older people, those in poor health, and also people with physical and mental disabilities. Mushrooms can be cultivated on both a small and large scale to allow for personal consumption, provision of a supplemental or principal income source, or the start of a commercial enterprise. Indeed, the basic requirements centre on an identified source for purchasing spawns, access to suitable substrates and the means to sterilize it, some bags and a clean, dark room to cultivate in. Alpha Mushroom Cluster is therefore seeking assistance from the government and its allied agencies such as the district assemblies to introduce mushroom cultivation in the rural areas for their personal consumption and marketing

Health improvement - The medicinal and nutritional value from the consumption of mushrooms cannot be over-emphasised. Increased cultivation and consumption of mushroom can therefore help raise the nutritional status of Ghanaians by providing an extra source of protein, valuable minerals and vitamins. The nutritional value and health benefits are listed below as follows:

Nutritional Values

1. **High Protein** content (19-40% of dry weight) contains sixteen (16) amino acids, including all the **nine (9) essential amino acids.**
2. **Low fat (1-8% of dry weight)**
3. No cholesterol
4. No starch at all. Low Calories
5. High **Fibre** content
6. Good source of **Folic Acid**
7. Multivitamin Source. Contains among others **B1, B2, B4, B6, B12 and C**
8. Minerals present includes: **Aluminium, Calcium, Copper, Iron, Potassium, Magnesium, Phosphate, Zinc,** etc,
9. Contains some **Antibiotics**

Health Benefits of Oyster Mushrooms

1. Strengthens the Immune System - thus little or no sickness.
2. Prevents the onset of all cancers (including Breast Cancer, Prostate Cancer)
3. Controls Hypertension and Diabetes
4. Promotes self-healing in minor infections and sores
5. Serves as a blood tonic
6. Serves as a good kidney tonic

The cultivation and processing of *Ganoderma lucidum*

The leadeship of the Alpha Mushroom Cluster in collaboration with the CSIR - Food Research Institute (FRI) is working hard on producing substrates for the cultivation and processing of *Ganoderma lucidum* to lower the risk of the occurrence of cancer and in particular the incidence of breast cancer amongst our womenfolk. Evidence of the potency of *Ganoderma lucidum* is all over the internet from research institutions and medical publication like PubMed as referenced below.

In a review article titled *"Anticancer effects of Ganoderma lucidum: a review of scientific evidence."* Yuen JW, et al. (Nutr Cancer. 2005) wrote:

> "Lingzhi" (Ganoderma lucidum), a popular medicinal mushroom, has been used in China for longevity and health promotion since ancient times. Investigations into the anticancer activity of lingzhi have been performed in both in vitro and in vivo studies, supporting its application for cancer treatment and prevention. The proposed anticancer activity of lingzhi has prompted its usage by cancer patients. It remains debatable as to whether lingzhi is a food supplement for health maintenance or actually a therapeutic "drug" for medical proposes. Thus far there has been no report of human trials using lingzhi as a direct anticancer agent, despite some evidence showing the usage of lingzhi as a potential supplement to cancer patients. Cellular immune responses and mitogenic reactivity of cancer patients have been enhanced by lingzhi, as reported in two randomized and one nonrandomized trials, and the quality of life of 65% of lung cancer patients improved in one study. The direct cytotoxic and anti-angiogenesis mechanisms of lingzhi have been established by in vitro studies; however, clinical studies should not be neglected to define the applicable dosage in vivo. At present, lingzhi is a health food supplement to support cancer patients, yet the evidence supporting the potential of direct in vivo anticancer effects should not be underestimated. Lingzhi or its products can be classified as an anticancer agent when current and more direct scientific evidence becomes available."

Writing under the title *"Clinical characteristics of gynecologic cancer patients who respond to salvage treatment with Lingzhi."*, Suprasert P, et al opined in the Asian Pac J Cancer Prev. 2014;15(10):4193-6. as follows:

> "Lingzhi or Ganoderma lucidum is a popular medicinal mushroom used as a health promotion herb in China and other Asian countries for thousands of years. There have many previous studies about the anti-cancer effects

> of lingzhi especially in vitro. The present study reports the clinical data of 5 gynecologic cancer patients who achieved stability in the disease after ingestion of lingzhi in the form of fruit body water extract and spores in a salvage setting. This report has been written to enhance the data describing the effect of lingzhi in cancer patients"

From all the above information it is very clear that embarking upon this project is the right thing to do to help curb the occurrence and increase of breast cancer in Ghana.

<u>Challenges of the Alpha Mushroom Cluster and the Mushroom Industry in Ghana and suggestions on how they can be overcome</u>
The challenges of the Mushroom Industry can be placed in 4 broad areas: Money and Motivation, Marketing, Machinery and Equipment, and finally Education and Awareness Creation

Money and Motivation – As has been said earlier, our members need financial assistance from the banks and financial institutions to expand the production base and improve their ideas of processing various innovative products. They also need motivation from the government through its agencies such as the Ministries of Agriculture and the Trade & Industry to assist mushroom farmers and producers to produce these products for export to increase the foreign exchange earnings of the country. This would go a long way to correct our balance of payments deficit, inflation and slow down the devaluation of our currency and decline of our economy.

Marketing – The members of Alpha Mushroom Cluster like other mushroom farmers are faced with the challenge of marketing their mushrooms locally as well as on the international market. The demand on the local market is not that strong as some Ghanaians see the cultivated mushrooms as artificial or inorganic and so prefer those picked from the forest which is seasonal and in short supply. On the other hand there is a huge demand for mushrooms on the international market and yet the mushroom industry is not yet able to produce enough to meet the demand. This is where the Ghana Export Promotion Authority (GEPA) should be able to assist the mushroom industry to train more mushroom producers to meet the demand and the Ghana Standards Authority should help them with meeting the international standards that are required for the international market through training and sensitization. Establishing marketing centres for mushrooms will also help in improving the marketability of mushrooms locally as well provide the needed publicity for the health benefits derived from the consumption of mushrooms.

Machinery and Equipment – Machines and equipment are definitely required for the value addition processing of the mushrooms whether for the export market or the local market and these machines are not cheap. Solar drying machines are needed to dry the mushrooms on a large scale and the canning machines to can them. To produce mushrooms for export some special purpose-built structures may have to be put up, complete with humidifiers and temperature controlling equipment, all of which cost a lot of money which the farmer may not be able to personally do this and therefore would require financial assistance from the banks and financial institutions.

Education and Awareness Creation – Ghanaians by nature are very traditional and so to be able to encourage them to consume more of the cultivated mushrooms which most people think are cultivated with unhealthy chemical inputs would require massive education to inform them of the benefits of using mushrooms and introduce them to cultivated mushrooms. The 'natural' mushrooms picked from the forest are seasonal in supply and more so the use of chemical fertilizers, weedicides and herbicides as well as bush-burning have made the naturally picked mushrooms, even more scarce in supply. There has to be a lot of publicity and educational programmes, both on radio TV and the social media circles. Educational campaigns in the schools, colleges and tertiary institutions will all go a long way to ensure that the education goes down to the homes and these can be more effectively organised by the Ministry of Education in collaboration with Alpha Mushroom Cluster.

Conclusion

Alpha Mushroom Cluster has come a long way from its humble beginnings in 2010 to date, but there is still a long way to go in the quest to make innovation the nexus of its entrepreneurial existence. There is a lot that needs to be done for its members and the mushroom industry as a whole to be able to draw out the potential that it has to change the economic fortunes of this country through the 3 main achievement goals of job creation, poverty alleviation and improving the health of our nation's citizens.

Thank you!

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Make More Money By Growing Mushrooms – Diversification Booklet 7

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PART 3: STIMULATING INNOVATION IN THE KEY SECTORS OF THE ECONOMY

ENHANCING SELF-SUFFICIENCY IN RICE PRODUCTION THROUGH INCREASED LOWLAND PRODUCTIVITY: THE "SAWAH" TECHNOLOGY OPTION

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Abstract

Rice is a major food in Ghana as all people consume it across the country. However, the country produces less than 40% of its annual rice requirements and hence relies on imports to make up the rest. Suitable land preparation, effective soil nutrient and water management options are key constraints that hinder the sustainable utilization of the over one million hectors of lowlands across the country. As parts of efforts towards addressing the above problems to improve local rice production, the CSIR- Soil Research Institute in collaboration with other partners developed the Sawah technology. This technology has production, ecological and living functions. There is improved water management, nutrient build up and soil conservation ultimately resulting in increased yield per unit area. Rice cultivation under the "Sawah" system at a few areas in Ghana has led to significant improvements in grain yields. Farmers currently obtain yields of over 6.0t ha^{-1} under the "Sawah" system as against the less than 2.0 t ha^{-1} under the traditional system. Sawah has the potential to ensure self-sufficiency in rice production in the country if only 30% of suitable land area is put under the "Sawah" technology.

Keywords: lowlands, improved soil and water management, rice, sustainability, "sawah".

1.0 Introduction

The Africa Rice Centre (2007) reported that, rice production in Africa has been expanding at a rate of 60% per annum, with 70% of the production increase due mainly to land expansion with only 3% attributed to an increase in productivity. As a result of erratic and diminishing rainfall amounts, much attention is now being given to lowlands as alternative sites for intensive crop cultivation, more especially rice in Ghana and in deed the West African sub-region. There has therefore been an increase in land use intensity particularly inland valleys, where water availability is currently guaranteed. However, water availability and high soil nutrient imbalances in lowland soils within and between agro-ecological zones of the West Africa sub-region are widespread (Buri et al; 1996, 1999, 2000; Issaka et al, 1996a, b, 1997). These soils, as recommended, require specific recommendations and sustainable management practices for effective development and utilization.

According to the Ministry of Food and Agriculture of Ghana (MoFA, 2009), rice has become the second most important food staple after maize in the country and its consumption keeps increasing as a result of population growth, urbanization and changes in consumer habits. MoFA (2009) further indicated that there has been large annual fluctuations in rice production which was largely attributed to changes in area (ha) put under rice cultivation, rather than per unit yield (tha^{-1}), emphasizing that Ghana depends largely on imported rice. Annual rice imports into Ghana between 2004 and 2013 is about US$228.5 million (MoFA, 2013). While area under rice cultivation increased yearly over the last decade, mean paddy yield is stagnated at 2.4 $t\ ha^{-1}$, which is only 40% of the achievable yield.

The continuous rise in the demand for rice has not only been met with increased imports but also with increased efforts at the local front to increase production. In Ghana, just like other crops, policy strategies on rice production over the years have been constantly changing. Policy strategies on rice by governments have been captured in Food and Agriculture Sector Development Policy (FASDEP I), Ghana Poverty Reduction Strategy (GPRS I & II), Medium Term Agricultural Development Programme (MTADP) and Medium Term Agricultural Sector Investment Plan (METASIP) which ended in 2015. All these policies have a common objective of promoting rice production towards ensuring food security and reducing poverty. According to the Ghana National Rice Development Strategy (G-NRDS) document, which is the supposed policy guideline for the period 2008 – 2018, rice production is proposed to be doubled taking into account the comparative production capacities of the three major ecologies (rain-fed upland, rain-fed lowland and irrigated). The document further stated that rice being one of the commodities identified for increased food security and import substitution, government intends to increase production through increased mechanization and cultivation of lowlands, mainly inland valleys amongst others.

While the savannah agro-ecological zones experience the lowest rainfall (< 1000mm) amounts for the year, the forest agro-ecological zones, on the other hand, experience relatively higher rainfall amounts (> 15000mm per annum) with a bimodal pattern. Thus different agro-ecological zones with different environments require different and specific management options for effective and sustainable utilization. Hence the need to design effective strategies for the sustainable development of lowlands for effective rice production in the country is long overdue. This paper looks at the contribution of the "Sawah" technology to rice production, its potential to enhance/ensure sustainable rice production and total contribution to food security when it is scaled up appropriately across the country.

2. 0 Methodology

Information was put together through field visits, interaction with farmers and a review of earlier works related to the "Sawah" technology. Rice production in Ghana is faced with several challenges and constraints. We looked at some of the major challenges/constraints, principles of the "Sawah" technology and results obtained with the development and introduction of the new technology to farmers. We further compared some of these results obtained under the new technology with production under traditional settings. Finally, a way forward to boost local rice production is proposed.

3.0 Results

3.1 Constraints to lowland development in Ghana

Major constraints to the use of lowlands in Ghana and indeed across the sub-Saharan Africa include poor soil, water and nutrient management, low mechanization and unfavourable land tenure systems. The land tenure system is a constraint to rice production in Ghana because of its general effects on both access to land and security over land ownership. The system tends to limit the size of holdings and investments towards land improvement, especially in the lowland rain-fed ecology as specifically outlined by MoFA (2011). Environmental degradation and declining soil productivity are major constraints due to poor land management particularly artisanal mining, logging and burning activities. Hence effective nutrient and water management options are lucking.

3.2 *Characteristics of lowland soils in Ghana*

Table 1 shows the fertility levels of lowlands soils in Ghana as compared to other regions of similar nature. From the table, soils of lowlands in Ghana are quite deficient in basic nutrients. Levels of both total Carbon and Nitrogen are low, available Phosphorus levels are very low and therefore very limiting. Exchangeable cations (K, Ca, Mg) are relatively higher for the forest agro-ecology than the savannah and are generally moderate to medium but with some areas showing potential K deficiencies. Soils of the savannah areas are also more acidic than those of the forest. Soil fertility levels (Table 1) as compared to similar regions of the world show that the sub-region (Ghana inclusive) to be quite deficient in available phosphorus and relatively lower in the basic cations particularly calcium and potassium, thus reflecting lower levels of eCEC. Mean topsoil pH of lowlands across the country is slightly acidic thus making them very suitable for rice cultivation. Physically the most extensive lowland soils in the Savannah agro-ecological zones are *Lima, Volta* and *Changnalili* series, which originate from shale and mudstone. These soils occupy generally flat, broad and very extensive lowland plains that are generally suitable for mechanization. Lowland soils within the forest agro-ecology, on the other hand, are developed from Lower Birimian rocks, where the valley bottoms are made up of *Temang and Oda series* which are poorly drained alluvial loamy sands and clays respectively. Even though most inland valley soils have low clay content (Table 1) they contain higher levels of silt. Soil texture is therefore Silt loam, with isolated areas being sandy loam across the northern part of the country while the south exhibits sandy loam through silt loam to loam textures. These soils are generally deep but have low water retention.

Table 1. Characteristics of lowlands soils in Ghana in comparison with West Africa and Tropical Asia

		Geographical Location		
Parameter		Ghana	West Africa	Tropical Asia
Samples (no.)		212	247	410
pH (water)		5.2	5.3	6.0
Total Carbon	(g kg^{-1})	9.05	12.3	14.1
Total Nitrogen	(g kg^{-1})	0.87	1.08	1.30
Av. Phosphorus	(mg kg^{-1})	3.2	8.4	17.6
Ex. Potassium	{cmol (+) kg^{-1}}	0.3	0.3	0.4
Ex. Calcium	{cmol (+) kg^{-1}}	4.8	2.8	10.4
Ex. Magnesium	{cmol (+) kg^{-1}}	2.55	1.3	5.5
Ex. Sodium	{cmol (+) kg^{-1}}	0.2	0.3	1.5
Effective CEC	{cmol (+) kg^{-1}}	8.5	5.8	17.8
Clay	(g kg^{-1})	96	230	280
Silt	(g kg^{-1})	554	-	-

Modified from Buri et al., 2010

3 3. "Sawah" system, "sawah" technology and its characteristics

(i) What is "Sawah" The concept and the term "Sawah" refers to man-made improved rice fields demarcated, bunded, puddled and levelled, rice fields with water inlets and outlets, which can be connected to various irrigation facilities such as irrigation canals, ponds, springs or pumps. "Sawah" creates the right micro-environment needed for proper rice growth and yields. Rain-fed "Sawah" without any irrigation facilities are also possible and are far better than rain-fed fields for rice growth without "Sawah".

(ii) What is Sawah Technology?

The sawah technology is the "site-specific, personal irrigated *sawah* system development and sawah system-based rice farming by African farmers' self-support efforts. The initial target was diverse inland valley agro-ecologies as primary rice ecologies in Ghana and Nigeria (Wakatsuki et al, 1998, 2001, 2010, 2011). This is due to casier water control by local farmers self-support efforts. However, since both wet and dry season trials during 2011-2014 on flood plains and inland basin (delta) of Sokoto and Niger river at Kebbi state of Sudan savanna zone at northern Nigeria, it became clear that some large flood plains as well as inland basins (deltas) in the Sudan savanna zone, such as Kebbi, Sokoto, Jigawa, Yobe and Borno states in Nigeria and Northern, Upper East and Volta regions in Ghana, should also be given higher priority if an appropriate cropping season can be selected to avoid flooding during August to October and using shallow groundwater tube wells, less than 10-20m depth.

*(iii) Cardinal Processes for "Sawah" Technology adoption***:** The *sawah* technology consists of four important skills and technologies. (a) site and right season selection (as these are significantly influenced by topography, soil type and hydrological condition) and site-specific correct *sawah* system design (based on land size, shape and slope), (b) skills for efficient and cost-effective *sawah* system development using appropriate agricultural machineries, such as high performance power tillers (greatly supported by beneficiary commitment and understanding), (c) rice farmers' socio-economic empowerment for the successful development and management of *sawah* systems, (farmer-group organization, land tenure arrangements, credit facilities, machinery handling), and (d) *sawah*-based intensive and effective rice agronomy (including variety selection and land, soil, water, and nutrient management to realize a minimum sustainable paddy yield of 4t ha^{-1}). The establishment of institutional training and dissemination systems for *sawah* technology transfer is necessary. The coordination of farmers' group formation and land-tenure arrangements for at least 10 years secured rent (Oladele et al., 2010) to sustain *sawah* development are also important. Training of lead *sawah* farmers is a key factor. The lead *sawah* farmers can train other farmers and farmers' groups to develop *sawah* and manage *sawah*-based rice farming by themselves. This is the final goal of our *sawah* technology implementation and endogenous development.

(iv) Where can "Sawah" be practised? "Sawah" rice cultivation can be done basically in the lowlands where water availability is guaranteed. However, considering the very diverse nature (Fig. 1) of rice growing environments in the sub-region, "sawah" can also be modified and adopted for the uplands. Several "Sawah" systems can be developed. Each system can be developed for a particular location based on existing conditions, water source, topography, slope etc. Various "Sawah" systems include (a) weir/dam/dyke and canal, (b) spring and canal (c) Pump and (d) Integrated

(v) *What are the advantages of "Sawah" system*? Economic benefits include: *(i)* increased grain yield, (ii) increased income, (iii) opportunity for rural employment *and* poverty reduction. Environmental benefits of "Sawah" include: (i) reduced soil erosion *(ii)* increased water availability (ponded water stays for a longer period, (iii) increased fertilizer use efficiency*, (iv)* increased organic matter accumulation and build-up, and (v) increased plant nutrient retention. The multi-functionality of "Sawah" system is presented in Table 2.

Table 2. Multi-functional nature of "Sawah" system of rice production

Function	Item
Production	1. Increase production per unit area 2. Soil improvement by deposition of silt in irrigation water 3. Maintain soil productivity
Ecological	1. Replenish groundwater resources 2. Stabilize river flow 3. Flood control by reducing peak flow (paddy fields act as reservoirs) 4. Prevent soil erosion 5. Recycling of water resources
Living	1. Promote communication and cooperation among villages via management organization systems 2. Stabilize peoples living (improved financial status) 3. Improve living environment and sanitation of farms

Adapted from Science Council of Japan (2001)

3.4: Increased Rice Yields as experienced under the "Sawah" technology in Ghana

Mean paddy yield for "Sawah" rice farmer-groups over the period 2001 to 2013 are given in Table 3 in comparison with national mean rice yields. There was a gradual and steady but significant yield increases throughout the period for "Sawah" rice farmers over the national mean. Mean yield for "Sawah" farmers increased from 4.5t ha^{-1} in 2001 to over 7.0 t ha^{-1} in 20013. There was a general increase in grain yield for all farmer-groups except for flood-damaged sites in 2003 and 2005. Mean grain yields for national production, on the other hand, remained steady and almost constant at 2.0 t ha^{-1} until 2008 and 2009 when mean yield exceeded 2.0t ha^{-1}. In comparison, mean yield under "Sawah" was three times more than the national means. Before the introduction of the "Sawah" system, mean rice yields under the traditional system hardly exceeded 2.0 t ha^{-1}.

Table 3. Mean paddy yield for "Sawah" eco-technology farmer-groups compared to National mean in Ghana

Year	Sawah Mean ($t\ ha^{-1}$)	National Actual Mean ($t\ ha^{-1}$)	National Achievable Yield ($t\ ha^{-1}$)
2001	4.5	1.9	6.5
2002	4.9	2.0	6.5
2003	5.1	2.0	6.5
2004	5.6	2.0	6.5
2005	5.0	2.0	6.5
2006	5.7	2.0	6.5
2007	5.7	1.7	6.5
2008	6.0	2.3	6.5
2009	6.1	2.4	6.5
2010	6.5	2.7	6.5
2011	6.6	1.4	6.5
2012	7.5	1.8	6.5
2013	6.8	1.8	6.5
2014	-	1.9	6.5

*Affected by floods; ** Facts and figures (MoFA, 2011); Figures in parenthesis represent national potential yield.

3.5: Improved fertilizer management and nutrient utilization under "sawah" eco-technology in Ghana

Under the "Sawah" system, rice response to mineral fertilizer additions has been positive and significant (Table 4). Rice response to nitrogen application increased significantly from non- application (0 kg N ha^{-1}) to a maximum (90kg N ha^{-1}) before levelling off. This trend was uniform for both sites for both 2004 and 2005. A similar trend was also observed for phosphorus application. Crop performance is greatly affected by its ability to utilize nutrients. Over the years, fertilizer management has been a major challenge for farmers in the lowlands mainly due to poor land and water management. Farmers tend to gain very little as larger amounts of applied mineral fertilizers are not utilized by the intended crop (due to nutrient loss through run-off and/or soil erosion). Under "Sawah" systems, rice responds to applied mineral fertilizer has been very great, indicating a significant utilization in the quantity of nutrients added from mineral fertilizer.

Table 4. Response to nutrient addition under the "Sawah" system in some lowlands in Ghana

(N-P_2O_5-K_2O) Kg ha^{-1}	Year 1	Year 2
0 – 0 – 0	0.96	1.07
0 - 90 – 90	1.34	1.47
90 - 0 – 90	2.01	2.06
90 - 90 – 0	3.03	2.42
90 - 90 - 90	6.96	6.95

3.6: Improved Nutrient Management as experienced under the "Sawah" technology in Ghana

Table 5 shows how both local soil amendments and mineral fertilizer can be used for nutrient management under the "Sawah" system. From Table 5, highest paddy yield was recorded from mineral fertilizer (8.37 t ha^{-1}) at Biemso 1 and this was followed by a combination of both mineral fertilizer and poultry manure (7.30 t ha^{-1}) at lower rates of application at the same site. The use of poultry manure alone at higher rates (7.0 t ha^{-1}) gave significantly higher yields of 5.96 and 7.30 t ha^{-1} at Potrikrom and Biemso 1 respectively. The affordability of mineral fertilizers by farmers is very limited as most rural farmers cannot afford the high cost of mineral fertilizers. Even though governments assist by providing subsidy on fertilizers, prices are sometimes still beyond the means of the small scale farmer. The relative abundance of local amendments and their use for soil fertility improvement is encouraged under the "Sawah" system.

Table 5. Effect of Integrated Nutrient Management under the "Sawah" eco-technology in lowlands in Ghana

	Paddy Yield (t ha^{-1})		
Treatments	Potrikrom	Beimso I	Biemso II
Control (no manure, no mineral fertilizer)	1.68	1.59	1.50
N-P_2O_5-K_2O (120-90-90) Kg ha^{-1}	6.77	8.37	4.03
N-P_2O_5-K_2O (90-60-60) Kg ha^{-1}	6.57	7.09	3.90
Poultry Manure (7.0t ha-1)	5.96	6.36	3.82
Poultry Manure (3.5 t ha^{-1}) + Mineral fertilizer (45-30-30)	6.25	7.30	4.15
Cattle Manure (7.0 t ha^{-1})	4.54	6.25	3.05
Cattle manure (3.5 t ha^{-1}) + Mineral fertilizer (45-30-30)	4.86	6.49	3.72
LSD (0.05)	0.99	2.14	0.84
Mean (site)	5.23	6.09	3.58
LSD (site)		0.52	

Adopted from- Buri et al, 2008

3.7: Improved Soil and Water Management under the sawah eco-technology

Table 6 shows the effect of improved and soil management under the "Sawah" system. All varieties responded positively (higher paddy yields) to improvement in soil and water management. Highest grain yield were recorded by all varieties, 8.2, 6.5, 7.8 and 7.6 t ha^{-1} for Bouake 189, Jasmine, Sikamo and Wita 7 respectively under bunded, puddled and levelled ("Sawah") conditions as against the other treatments. The trend was similar for the second year with better land preparation and good water management giving the highest grain yield for all varieties. Paddy yields increased in the order: farmers practice < bunded only < bunded and puddled < bunded, puddled and levelled rice fields (Table 6). Under the "Sawah" systems, simple, effective and cost effective water management structures are put in place. The provision of such water management structures (construction of bunds) greatly improves water utilization. This will make more farmers adopt water harvesting for use on their rice fields. Luck of proper soil and water management has been a major challenge to rice production across all agro-ecological zones in the country.

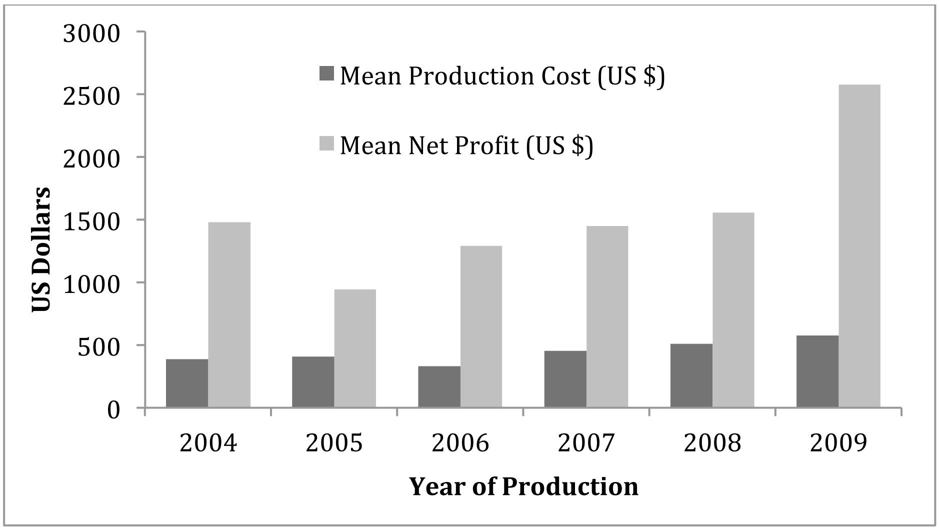
Table 6. Rice response to improved water management as experienced under the "Sawah" technology in Ghana

Management	Rice Variety				
	Bouake 189	Jasmine 85	Sikamo	Wita 7	Mean
Year 1					
Farmers practice (no water control)	3.9	3.8	3.2	3.3	3.6
Only bunded	5.1	4.9	5.1	5.3	5.1
Bunded and puddled	6.8	5.5	6.5	6.2	6.3
Bunded, puddled and levelled	8.2	6.5	7.8	7.6	7.5
Mean	6.0	5.2	5.7	5.6	-
Year 2					
Farmers practice (no water control)	3.5	3.7	2.2	3.3	3.2
Only bunded	4.2	4.0	3.2	4.5	4.0
Bunded and puddled	4.8	4.5	4.3	4.9	4.6
Bunded, puddled and levelled	6.2	5.5	5.6	5.4	5.7
Mean	4.7	4.4	3.8	4.5	-
SE for each year	1.12				

Source – Issaka et al, 2008

3.8: Increased revenue and rural employment generation as experienced under the "Sawah" technology in Ghana

Mean estimated revenue for "Sawah" rice farmer- group is presented Figure 1. While cost of production remained relatively similar and low across years, production of rice significantly increased leading to higher revenue. Highest net profits were recorded in 2009 while lowest profits were recorded in 2005, due to late floods that destroyed most farms. Production cost per ha ranged from US $300 to US $ 500 across years, while net profits ranged from 1000-2500. Increased paddy yields under the "Sawah" system (Table 3), will ultimately result in increased revenue for farmers when an effective marketing system is put in place. Under such circumstance, there is room for reduced rural poverty and guaranteed food security.



Source – Buri et al., 2010

Fig. 1: Effect of "Sawah" eco-technology on production and income generation among farmers in Ghana

3.9: Cost effectiveness of "Sawah" eco-technology

Cost estimated for various irrigation systems are compared to the "Sawah" system in Table 7. While Overseas Development Assistance (ODA) projects may cost between US $(20000 - 30000) and US$ (10000 – 20000) for the development of one hector of irrigated land, the "Sawah" approach uses US $(1000 – 3000) for the same area of land for irrigation. The "Sawah" eco-technology can therefore provide the same scale of development using about 10% of the cost of large to medium scale irrigation projects in Africa. While gross revenue and yields remain the same for all systems, running cost of the "Sawah" system is lower thus resulting in higher net revenue. Farmer participation in the "Sawah" system is higher, project ownership is with the famer and hence adoption is relatively higher than other systems because of on-the-job training, a major characteristic of the "Sawah" approach. Cost-effective development of our lowlands is critical for sustainability. Initial "Sawah" development relies heavily on the use of the power tiller, which makes up 50% of the developmental cost. Therefore, apart from the importance of training power-tiller operators, high-quality, durable, and low-cost power tillers are necessary. Once "Sawah" is developed, power- tiller cost for rice farming becomes minimal and affordable to the resource- poor farmer. With proper and effective training of farmers on "Sawah" development, "Sawah"-based rice farming is more sustainable than old-style ODA-based irrigation projects, even though there may be a need for special subsidization to encourage "Sawah" development by farmers during the first year.

Table 7. Comparison of "Sawah" system development with large and small-scale ODA-based developments and the traditional rice cultivation system in inland valleys of Ghana and Nigeria.

	ODA large-scale development	ODA small-scale development	"Sawah" Approach	Traditional system
Development cost ($/ha)	20,000 – 30,000	10,000 – 30,000	1,000 – 3,000	30 – 60
Gross revenue ($/ha)	2,000 – 3,000	2,000 – 3,000	2,000 – 3,000	500 – 1,000
Av. Yield (t/ha)	4 – 6	4 – 6	4 – 6	1 – 2
Running cost, including machinery ($/ha)	600 – 800	600 – 800	400 – 600	200 – 300
Farmer participation	Low	Medium – High	High	High
Project ownership	Government	Government	Farmer	Farmer
Adoption of technology	Slow and difficult	Slow and relatively easy	Medium to high technology transfer through on-the-job training	Low technology transfer
Sustainable development	Low (heavy machinery used by contractors in development	Low to medium	High (farmer-based and small power-tiller used in development and management)	Medium
Management	Difficult	Difficult	Easy	Easy
Adverse environmental effect	High	Medium	Low	Medium

Adopted from Wakatsuki et al., 2011.

3.10: Increased Soil Productivity and Environmental Conservation under "Sawah" eco-technology

Figure 2 shows changes in levels of selected soil fertility parameters over the period. There was a build-up (positive change) for most nutrient elements. While total carbon levels rose by a mean of 3.2%, exchangeable cations levels rose by 33.5%, 26% and 11% for Potassium, Calcium and Magnesium respectively. However, total nitrogen and available phosphorus levels reduced by 3.7% and 20.0% respectively. This brings to focus, the highly deficient nature of our soils in P in particular. Most soils are low in P and this coupled with high fixation capacities results in serious P deficiency. Most of the exchangeable cations (Ca, Mg, Na) showed strong accumulation. There is a significant reduction in soil degradation and increased erosion control under the "Sawah" system as such nutrient accumulation will improve soil productivity.

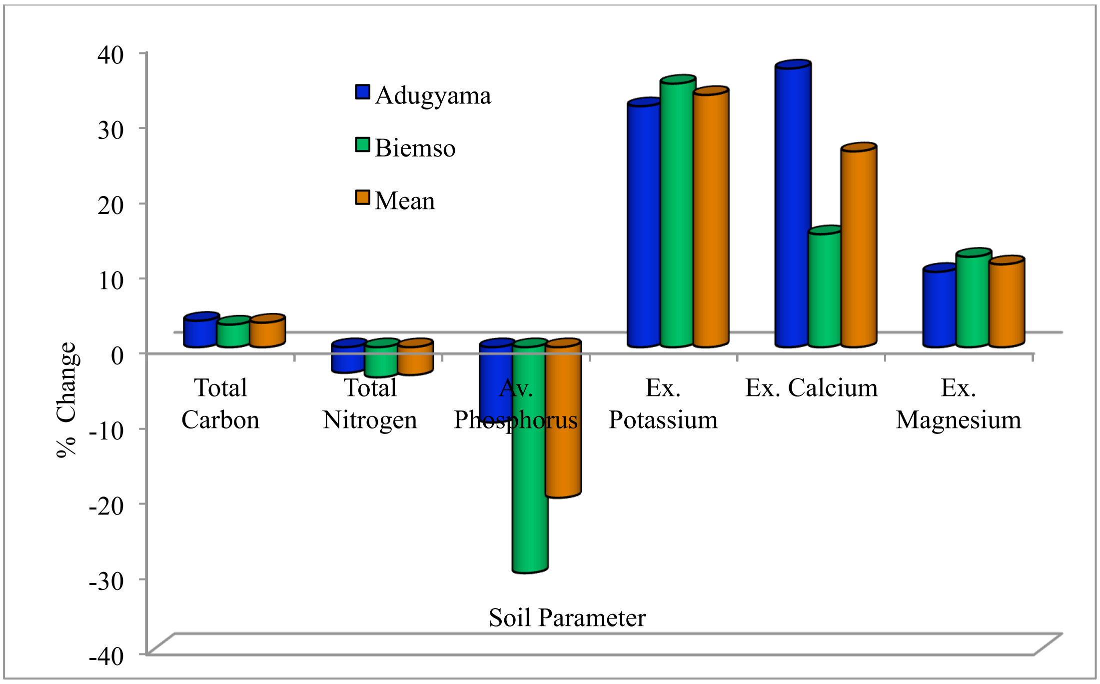


Fig. 2. Changes in topsoil (0-30cm) nutrient levels under "Sawah" eco-technology over 10 years in some lowlands in Ghana

Source - Buri et al, (2010)

3.11: Suitability for low-cost mechanization with little environmental degradation.

To reduce drudgery and promote mechanization for greater impact, the basic machinery if available is the power tiller. This is a small and lighter machine with a higher efficiency and less negative impact on soil (compaction, erosion) and easily affordable by the average farmer. As compared to other machines, which are bigger, heavier and more expensive, the power tiller is more economical and suitable for mechanized land preparation in the lowlands. Effective land preparation for seeding is a major challenge to rice farmers, as it has a direct bearing on crop growth and fertilizer utilization by the crop. Mechanization of rice production activities is very necessary if high production and productivity are to be achieved. The use of such simple machinery is strongly encouraged under the "Sawah" system.

Discussion

General rice production in Ghana

In Ghana, and indeed the West Africa sub-region, experience has shown that both large-scale and small-scale irrigation projects, typically created with Overseas Development Assistance (ODA), have been very costly because of dependence on heavy engineering works and outside expertise (Wakatsuki et al, 2011). Due to high construction costs, economic returns from such projects remain negligible or negative for a long period of time and project ownership remains with the government rather than with farmers. The development and management of most ODA projects have not been sustainable and therefore not yielded the expected results. Several of such high cost projects have been implemented across many countries in West Africa. In Ghana, even though yields under such project remain low (< 4.0 t ha^{-1}), land development involved the use of heavy machinery like tractors and bull dozers which have proved to be unsuitable for our soils and environment.

With the execution of several rice projects, the general expectation is that national rice production will significantly increase with improvement in productivity. However, this has not been the case as rice production has only marginally increased due to extensive cultivation (more cultivated area) rather than increase per unit area (intensive cultivation). According to yearly production figures from MoFA, achieved paddy yields have been only 20-25% of potential yield (6.5 t ha^{-1}). Reasons for such low recorded yields by farmers and the inability of most rice projects to achieve set targets and goals within the inland valleys may be due to the non-availability of improved technologies, low or no adoption of such improved and more production oriented technologies if available, use of unsuitable tools/machinery and the execution of rice projects without the direct input and involvement of beneficiaries (farmers).

Rice Production under the "Sawah" system

"Sawah" promotes intensive rather than extensive cultivation and will thus make a positive and significant contribution to local rice production while also enhancing reduced land degradation and promoting environmental conservation. Buri et al (2007) reported of significant responses to mineral fertilizer application from rice under the "Sawah" systems (Table 4) in selected valleys in southern Ghana. With improved water management under "Sawah" system, nutrient availability is increased and hence, its uptake by the rice crop. There are several soil amendments which are common and available in most rice growing communities. The use of such materials to compliment mineral fertilization provides a sustainable nutrient management system and therefore promoted under the "Sawah" system. The recycling of farm organic matter (residues) is therefore very helpful and may be used directly on rice fields or treated (compost, ashed, charred).

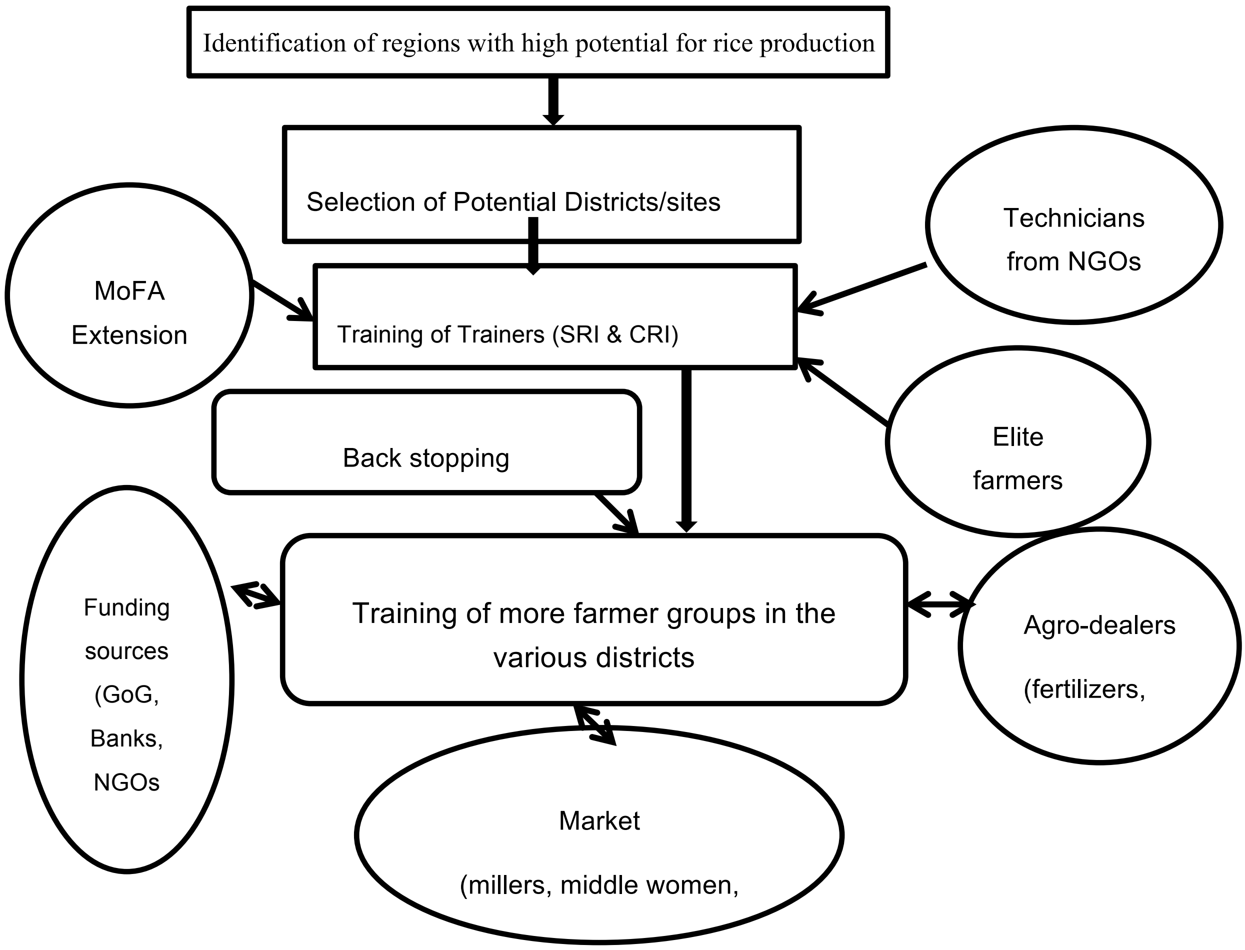
Lowland soils, including inland valleys across the West African sub-region, have been observed to be generally low in fertility (Issaka et al, 1999a, b, 1997, Buri et al, 1996, 1998, 2000, 2010). The build-up of soil nutrients under the "Sawah" system (Buri et al, 2011) can help to improve and/or maintain soil fertility levels. Darmawan (2011) also observed that the "Sawah" system was very productive as a study conducted over 33 years (1970-2003) in Indonesia showed a net accumulation of organic matter in" Sawah" fields over non "Sawah" fields. Darmawan reported that total carbon (TC) and total nitrogen (TN) contents significantly increased from 31.90 to 40.42 Mg ha^{-1} and from 3.04 to 3.97 Mg ha^{-1}, respectively on "Sawah" farms. While looking at the effect of "Sawah" on soil physical characteristics, Oppong and Wakatsuki (2011) observed a positive and linear relationship (r^2 = 0.84) between the degree of saturation and rice yield on "Sawah" fields as against no-"Sawah" fields. The authors attributed such observations to the high organic matter content and its associated favourable nutrient content, low compaction and positive degree of saturation due to low permeability on "Sawah" soils. Similar observations have also been made from studies on "Sawah" fields in Nigeria (Nwite et al., 2010, 2011).

Major machinery used is the power tiller (two-wheel tractor). After a five year usage of the power tiller across several locations and agro-ecological zones in Nigeria, Dada-Joel et al, (2011) concluded that power tiller is the appropriate machinery for mechanizing lowland preparation for rice production as it is suitable for both primary and secondary tillage operations. Its light weight makes it more favourable for work on our fragile ecosystems and soils, which are easily and permanent damaged by the use of heavy machinery. Similar experiences were also shared by rice farmers working in the lowlands of Ghana. For affordability, (power tiller is relatively cheaper than the tractor), average size of farm, economic situation of the poor resource farmer and negative effects of the use of heavy machinery (tractors, bulldozers, etc.), the power tiller is the most appropriate machine for mechanizing inland valley rice farming. Mass adoption of the machinery will also lead to local manufacture of most components giving rise to employment opportunities for many people. It should, however, be noted that the use of heavy machinery such as bulldozers and large size tractors, is not suitable for the lowlands as they permanently destroy the environment and accelerate degradation processes. Results obtained show that the "Sawah" technology has brought about tremendous improvement in rice yields. Grain yield has increased from less than 2.0 t ha^{-1} under the traditional system to more than 6.0 t ha^{-1} under the "Sawah" system. With such higher yields, the presence of guaranteed markets and minimum support can serve as motivation for more farmers to go into rice production under the "Sawah" system. Incomes of farmers will also correspondingly and significantly increase. Comparing yields of "Sawah" farmers with yields of farmers from similar environments (Table 2), the "Sawah" system has shown the potential to support and promote increased local rice production. Mean national paddy yield over the past decade has been around 2.4 t ha^{-1} covering an area of 165,000 ha. Under the "Sawah" technology with mean paddy yield of over 6.0 t ha^{-1}, Ghana can increase rice yields by over 300% with less than 30% of the current area cultivated to rice. A wider scale adoption of "Sawah" can revolutionize rice production in sub-Saharan Africa by 2030.

Proposed Strategy for Lowland Development: The "Sawah" Approach

Results so far obtained under the "Sawah" system show its great potential for the sustainable use of inland valleys and increased rice production in the country. With the "Sawah" system, emphasis is being laid on the development of small scale projects where beneficiaries (farmers) are fully involved in their execution and eventually become managers of such projects. This is the basis of the "Sawah" approach. The schematic diagram (Figure 3) shows the necessary steps for the scaling up of the "Sawah" technology in Ghana. It shows the identification of potential areas for rice development and the need for serious capacity building (human resource development) for effective and proper take-off. Initial capital investment may be beyond the reach of the poor small scale farmer. Hence strong linkage with funding sources is imperative. Linkage with agro-dealers, markets and a strong back-stopping from research institutions completes the circuit.

To make rice cultivation more attractive, a more simple, effective, sustainable, eco-friendly and easy to adopt approach ("Sawah" eco-technology) is therefore proposed for the development of the country's inland valleys in particular and lowlands in general. The "Sawah" system offers low-cost irrigation and water control mechanisms and land development processes (Tables 6 & 8), with full farmer participation. This does not only give the farmer ownership of the system but also makes him more responsible for its operation (sustainability).



CSIR – Council for Scientitific and Industrial Research, ; MoFA – Ministry of Food and Agriculture, GOG – Government of Ghana, NGO- Non-governmental Organizations, FBO – Farmer Based Organization.

Figure 3. Steps for up-scaling "sawah" system of rice production in Ghana

African lowlands contain heterogeneous topographies and low fertility (Table 1) because of weak lowland formation as compared to those in Asia. Therefore, careful site-specific development and management technologies must be disseminated through intensive on-the-job training (OJT). The development and management of “Sawah” systems requires that local farmers are self-motivated and have access to small-scale equipment, such as the power tiller. Most inland valleys are small in size and heavy machinery usage is detrimental to the environment. The “Sawah” approach simply involves the construction of bunds, puddling and levelling to improve water management and nutrient uptake, with simple and cheaper water harvesting methods, using local materials (e. g. sand bags, wood) through weirs, ponds, springs etc. After almost a decade (1997-2011) of numerous innovation processes, the “Sawah” system was successfully adopted and tested in Ghana and Nigeria, especially in locations where appropriate sites were selected, local leading farmers trained, and proper backstopping provided. Results obtained have been very good and encouraging. The system has therefore been identified as promising and what is currently needed is scaling up for the benefit of rice farmers across the country.

Through bunding, puddling and levelling under the “Sawah” system, nutrient deficiency limitations can be corrected in addition to improved organic matter management (Fig. 2). The system is intrinsic and conservative and can help improve and/or maintain nutrient levels within these rice growing micro-environments The “Sawah” approach involves four important skills and technologies: (i) site selection and site-specific “Sawah” system design, (ii) skills for cost-effective “Sawah” system development using a small power tiller, (iii) rice farmers’ empowerment for the successful development and management of “Sawah” systems, and (iv) “Sawah”-based rice agronomy, including best variety selection and management. There is therefore the need for the establishment of institutional training and dissemination mechanisms for “Sawah” eco-technology transfer. The coordination and formation of farmer-groups and land-tenure arrangements such as secured rent or more sustainable rental condition are critical to sustain “Sawah” development. Training of lead-farmers is very important as such farmers can train other farmers or farmers'-groups to develop “Sawah” and manage “Sawah”-based rice farming by themselves. Without any training for “Sawah” system management by beneficiaries, systems put in place will not function effectively and efficiently. This is a key component of the “Sawah” eco-technology and a major difference between other systems. The technology can be transferred from farmer to farmer, and enough leading farmers can be trained nation-wide. Thus, what is needed now is large-scale dissemination of the technology for in inland valleys rice production across all major agro-ecological zones in the ten (10) regions of Ghana.

Conclusion:

The “Sawah” technology which relies on intensification rather than extensive cultivation leads to significant increases in yield per unit area. This does not only result improved production levels but also in a significant reduction in total area of land cultivated. Hence a reduction in environmental degradation currently associated and aggravated by extensive crop cultivation. To make a national impact, the technology needs to be introduced to more rice farmers across all ago-ecological zones either through policy, legislation or otherwise.

In line with government's aim of modernizing agriculture, the "Sawah" technology presents a great opportunity for Ghana to be a net exporter of rice in the not too distant future. Ghana and indeed the whole of the West African sub-region can significantly increase rice production if only 30% of current rice lands can be put under the "Sawah" system of rice cultivation.

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UPSCALING INTEGRATED FIELD AND STORED PEST MANAGEMENT AND APPROPRIATE POST HARVEST HANDLING PRACTICES TO EXTEND SHELF- LIFE OF YAM

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Abstract

The West Africa Agricultural Productivity Programme (WAAPP) funded project carried out by Council for Scientific and Industrial Research-Savanna Agricultural Research Institute (CSIR-SARI) between 2009-2012 generated strategies for integrated management of field and storage pests as well as post-harvest handling to extend shelf-life of yam. A new project, CSIR-Technology Development and Transfer Centre (CSIR-TDTC), in collaboration with the CSIR-SARI up-scaled the findings from the WAAPP project to some enterprising yam farmers in the Mion district of the Northern region of Ghana. The project was carried out in three communities, namely Salankpang, Kulinkpegu No. 1 and Kulinkpegu No. 2. The objectives of the project were to increase availability of yam setts at planting, to increase yam production and to extend shelf-life of yam. The dissemination strategies used included: contact meetings, trainings, field demonstrations and farmer field schools (FFS). The contact meetings were used to engage the farmers in participatory problem identification and strategies to overcome them. The field demonstrations were used to practically expose farmers to integrated strategies to address their production constraints. The integrated strategies used in the field demonstrations included, mounding, yam sett treatment, yam beetle control and good harvesting and post-harvest handling practices. The farmers were also trained through demonstrations by adopting the farmer field school approach. The quantity of yam setts produced by the enterprise farmers using mini-sett technology ranged from 1,500 to 4,000 setts from a quarter of an acre or less. Benefit cost ratio (BCR) showed an average of GhC 3.0 gain on every GhC 1.0 invested in mini sett technology. Tuber yield (kg/ha) was significantly ($P<0.05$) higher in the treated plots than the control. Higher number and bigger size tubers were obtained from the treated

plots compared with the control. Other key achievements included; increased plant population (177 %), increased sprouting (95 %), reduced yam beetle infestation (about 80 %), complete elimination of rodent attack in storage structure, extended storage period up to seven months and increased yam setts production. It is therefore recommended that these technologies should be up-scaled to other enterprise farmers in other major yam producing communities in Ghana.

Key words: Yam, Mini-sett, postharvest, shelf-life, technology, integrated strategies, TDTC

Introduction

The West Africa Agricultural Productivity Programme (WAAPP) in the year 2009 funded the project WAAPP 003: Integrated management of field, storage pests and post-harvest handling to extend shelf-life of yam. The project was successfully implemented in Northern and Upper West Regions in Ghana by CSIR-SARI in collaboration with Ministry of Food and Agriculture (MoFA), Farmer Based Organizations (FBOs) and Non-Governmental Oganisations (NGOs). The findings from the three-year project were subsequently packaged to be disseminated to yam farmers in the major yam growing zones in Ghana. However, lack of funding delayed the dissemination of the technologies for close to three years. The intervention from CSIR-TDTC project to support CSIR-SARI to up-scale the improved yam technologies generated under WAAPP 1A 003 project was therefore seen as a dream come through.

The dissemination project was implemented in the Mion District in Northern Region of Ghana. About six hundred enterprise yam farmers were targeted by the project. The project aimed at increasing availability of yam setts, increasing yam production and extending the shelf-life of yam through integrated management of field and storage pests and diseases as well as improved postharvest handling and storage. The target beneficiaries of the project were the private enterprise yam farmers in three communities in the Mion District. The communities were Salankpang, Kulinkpegu No. 1 and Kulinkpegu No. 2. The Chairman of the Mion District Yam Farmers' Association assisted in the selection of these communities based on the presence of vibrant private enterprise yam farmers who needed to be trained in improved yam production technologies to enhance their productivity. Also based on the willingness of the yam farmers to go into yam setts production using the yam-mini-sett technology, thirty farmers were selected from the three communities for yam sett production. This is because non availability of yam setts has been reported to rank very high among constraints of yam production in Northern Ghana (Kusi *et al.,* 2013). This is mainly due to low multiplication rate of a yam tuber under farmer's practice (less than 10 setts over a season) as compared to a single seed of cereal like maize which can be multiplied into over 100 seeds over a cropping season. In the late 1970s, the "mini-setts technique" was developed as a technique for the production of seed tubers; different from the production of ware yam **(**Adegboyega *et al*., 2010)**.** The technique utilizes a small (20-50 g) part of a whole non-dormant tuber containing periderm and some cortex parenchyma. The mini-sett is sown and the resulting tuber is sufficiently large to serve as a seed tuber for the production of food or ware tubers (Adegboyega *et al*., 2010).

Materials and methods

Contact meetings were organised in each of the project communities to identify private enterprise yam Farmer Based Oganisations (FBOs) as well as individuals who were willing to go into yam setts production using the mini-sett technology. A total of 600 private enterprise yam farmers were contacted by the project through the FBOs. A total of 200 farmers were selected from each community out of which 10 of them were selected as those who were willing to take up yam setts production as a business using the mini-sett technology.

The farmers were engaged in discussion during the contact meetings to identify their major production constraints. The following key technologies and production strategies were therefore identified for dissemination to alleviate their production constraints

i. Site selection (avoiding fields closer to water bodies which serve as breeding site for yam tuber beetles)
ii. Optimum spacing for yam mounds
iii. Pre-planting treatment of yam sett with either wood ash or chemical insecticide and fungicide mix
iv. Post-sprouting treatments to control yam tuber beetle
v. Good agricultural practices (prompt weed management, earthing-up, staking, prompt harvesting etc.)
vi. Yam setts production technologies (mini-sett technique)
vii. Improved yam storage
viii. Good postharvest management practices

Field and storage demonstrations as well as training in farmer field schools (FFSs) were used to disseminate these technologies to the yam enterprise farmers. To enhance the adoption of these technologies and production strategies by the farmers, hands on practical approach was adopted to train them at the demonstration sites. They thus learnt through practicing what was thought. This involved guiding them to maintain the demonstration plots and carrying out all the recommended practices themselves to ensure their active participation in the project implementation.

The practical training sessions during FFSs at the demonstration sites covered topics on land preparation, planting, pre-planting treatment of yam setts and other good agronomic practices such as staking, early weed management, spraying against yam tuber beetle and earthing up.

The pre-planting treatment introduced and demonstrated were;

i. Insecticide[1] + fungicide[2] mix

ii. Wood ash
iii. No treatment (farmer practice)

[1]Lambda cyhalothrin (Lambda Supper® 2.5 EC), a synthetic pyrethroid, at the rate of 20 g active ingredient ha-1. [2]Folpet, 500 g per kilo (product: Falpan 50 WP).

Mode of application of treatments

The yam setts were treated with chemical pesticides by immersing them in both insecticide and fungicide solution for 15 minutes and dried under shade for 30 minutes before planting (Kusi *et al*., 2013). On the other hand, the yam setts were treated with wood ash by immersing them in slurry of 2 parts of wood ash into 5 parts of water for 15 min. The setts were removed and dried under shade before planting (Kusi *et al*., 2013).

The no treatment or control represented the farmer practice where yam setts are planted without treatment and no spraying from 12 weeks after planting against yam beetle infestation. The post sprouting treatment was carried out by spraying insecticide (Lambda cyhalothrin) weekly for three continuous weeks starting from 12 weeks after planting. The mounds were mulched with grass to provide protective cover for the yam sett and protect the newly emerging sprouts against sunshine and excessive heat when they emerge freshly.

The farmers were involved in data collection during the period of training on the demonstrations to enable them appreciate the importance of the pre-planting treatment of the yam sett as well as Good Agricultural Practices (GAPs) for yam cultivation.

The project also facilitated the adoption of yam mini-sett technology as a business by selected farmers. Training in good harvesting practices and construction and use of improved storage structure was also carried out. The improved storage structure was constructed with locally available materials such as woven thatch, wooden poles and rafters as well as thatch roof. The only material that was purchased outside the farming community is the roofing sheets used to construct fence to eliminate rodents' access into the storage structure which could be used for 5 or more years before changing it.

Data collection

Data collected during the study included:
Number of mounts per plot
Number of sprouts at 8 weeks after planting
Number plants at harvest
Number of tubers with yam beetle damage
Tuber yield per plot

The farmers were also guided to assess the following data as part of the training
Checking the distance between mounds
Assess sprout vigour
Pest and diseases incidence
Assess the effects of spacing on weed incidence, erosion, canopy formation and moisture conservation
Scouting for yam beetle from 12 weeks after planting.

Results and discussion
The following were identified by the farmers during the contact meetings as their major contrainst to yam production:
i. Scarcity and high cost of labour
ii. Incidence of pests and diseases (yam beetle)
iii. Lack of improved storage structures
iv. Low productivity
v. Inadequate planting materials

In Northern and Upper West Regions of Ghana, Asante *et al*., (2007), identified insect pests, nematodes and diseases which attack yam both on the field and in storage among the major constraints of yam production. Obeng-Ofori, 1998, identified the following as major constraints to yam production on a large scale: high cost, and often, unavailability of planting materials, scarcity and high cost of labour, declining soil fertility and lack of staking materials especially in the Guinea Savanna zone of Ghana. The constraints identified by the farmers during the contact meetings therefore did not deviate from the earlier constraints identified by these authors.

Land preparation
The evaluation of farmer's practices in land preparation and planting revealed that farmers preferred bigger yam mounds widely spaced at about 2 m x 2 m (Fig. 1) giving a total of about 2500 yam mounds per hectare. On the other hand, the recommended spacing for yam mounds at 1.2 m x 1.2 m (Fig. 2) gave a total of about 6944 yam mounds per hectare which resulted in 177.79% increase in mounds over the farmers practice.

Large yam mounds (widely spaced at approximately 2 meters apart) observed on farmers' plots could be attributed to two major factors. The farmers believe larger mounds produce bigger yam tubers because of the large volume of soil gathered for the tuber development. Secondly, some of the farmers who use hired labour to prepare their yam mounds attributed the large and widely spaced mounds to the contract agreement they have with the hired labourers. Because they charge per area and not per yam mound, the hired labour space the yam mounds wider in order to cover the area within a short time. The farmers were therefore educated during the FFSs to rather negotiate with the hired labour per yam mound and not per area in order to get the labourers to agree to prepare the mounds based on the recommended spacing. The farmers were further educated about the need to utilize space effectively to maximize productivity.

They were made to know that the trend of demand is changing from bigger tuber size to medium and smaller tuber size in the urban and international markets. Factors such as ease of handling and transporting, smaller family size, fast decaying and loss of quality and taste of yam when a piece is left overnight makes the consumers prefer medium size yam tuber to the larger tubers. The farmers corroborated this by adding that when the middle men from the cities come to buy yam they usually select against very big tubers. The farmers who also double as aggregators for the middle men also said they are able to load more small to medium sized tubers per truck than bigger tubers, which give them better returns.

The farmers were then taken through other advantages they stand to gain if they should adopt the recommended spacing. These include reduced cost of production in terms of cost of ploughing and labour for weed control because they can just work on only one hectare and yet achieve the number of yam mounds they will get on over two and half hectares. Again, they were also made to know that the closer spacing achieved by adopting the recommended spacing will lead to early canopy formation that will minimise growth of weeds, check erosion and conserve soil moisture to promote growth and development of the crops. Adoption of the recommended spacing could also reduce the number of stakes and cost of staking because a minimum of four plants can be directed to one stake, which is not possible when yam mounds are widely spaced.

Planting and sprouting

The number of sprouted setts recorded at 8 weeks after planting is presented in Fig. 3. Significant difference ($P>0.05$) was observed between the treated plots and the control. However, there was no significant difference between the insecticide + fungicide treatment and the wood ash treatment. The control recorded significantly lower number of sprouts at eight weeks after planting. The number of plants that survived after sprouting till harvest is presented in Fig 4. Here again significant number of plants were lost in the control plot than the wood ash and the insecticide + fungicide treated plots. There were however, no significant difference between the wood ash and the insecticide +fungicide treated plots. There was as high as 9% reduction of plant stands between 8 weeks after planting and the time of harvesting.

The training in pre-planting treatments and the results from the treated fields was enough to convince the farmers that treatment of yam setts is necessary to control insect pests and disease causing organisms found in storage and in the soil. This was presented to them as part of the integrated production system that ensures good sprouting and crop establishment. The importance of planting disease and/or pest free setts was adequately demonstrated to the farmers using the differences in the number of sprouted setts. The significantly low number of sprouts recorded against the control plots was therefore used to prove to the farmers the need to protect the setts at planting. At the stage of sprouting and early establishment, the plants were so vulnerable that stress conditions such as pest and diseases attack could seriously affect their growth and development (Kusi *et al.*, 2013). For soil-borne pests and diseases such as nematodes and *Sclerotium* wilt diseases, Amusa *et al.* (2003) recommended planting of disease-free yam setts as an effective way of reducing nematode problems. Osai (1993) also recommended treatment of yam setts with a suspension of fungicide (Fernasan D*)* or wood ash. Plant parasitic nematodes cause unappealing, warty or knobby appearances on yam resulting in extremely low market value of tubers (Amusa *et al*., 2003; Olabiyi and Ogunbowale, 2010). Nematodes have also been found to cause decay of yam tubers known as dry rot disease of yam which occurs in the outer 1 to 2 cm of tubers (Amusa *et al*., 2003).

The data on the difference between the number of sprouts at 8 weeks after planting and the number of plants at harvest served to further lay emphasis on the importance of selecting healthy setts and treating the setts at planting in order to obtain vigorous plant stands after sprouting. These could therefore withstand any stress conditions such as dry spells, pests and diseases attack later in the season. The farmers were therefore engaged in discussions during the training sessions to identify possible reasons or causes of the high plant loss in the control plots. One of the major factors identified was that the sprouted setts on the control plots in all the communities were not as vigorous as in the treated plots. So the dry spell experienced during the 2015 cropping season had much effect on the less vigorous plants, hence the high loss of plants in the control plots. Asare-Bediako *et al*., 2007, also reported that the number of plants that could not survive after sprouting till harvesting could mean that they sprouted out of rotten tubers.

Tuber beetle damage

The mean number of tubers found to have been damaged or having the feeding holes of yam beetle is presented in Fig. 5. The control plots in all the three communities recorded significantly higher number of tubers with feeding holes of yam tuber beetles than the wood ash and the insecticide +fungicide treated plots. The number of feeding holes of yam beetles recorded against the yam tubers harvested from the wood ash and the insecticide +fungicide treated plots were not significantly different. The control plot recorded as much as over three times more tubers with yam beetle feeding holes than the treated plots.

The overall tuber yield in kg ha^{-1} is presented in Fig. 6. The tuber yield in the treated plots were significantly higher than the control plot. Higher numbers of tubers were harvested from the treated plots than those harvested from the control plots. Harvested tubers were also bigger in treated than for control plots. The insecticide + fungicide treated plot also recorded significantly higher tuber yield than the wood ash treated plot.

Yam beetle attack has been identified as one of the major production constraints in the yam growing zone in northern Ghana. Their incidence and damage are very severe on fields established along or close to rivers, streams and other water bodies that the insect use as breeding sites (Obeng-Ofori, 1998). The yam beetles embark on feeding migration usually around 12 weeks after planting of yam to feed till they are sexually matured when they return to their breeding sites to continue their reproduction cycle. The treated plots were therefore protected by weekly spraying of insecticides (Lambda cyhalothrin) on the yam mounds over a period of three weeks starting from the 12 weeks after planting (Kusi *et al*., 2013). This resulted in significant low number of yam tubers with yam beetle feeding holes and this signifies the importance of the post sprouted treatment from 12 weeks after planting. The farmers appreciated the timing of the spraying which coincided with the feeding migration of the yam beetles because it significantly reduced the incidence and damage in the treated plots. The choice of insecticide for the weekly spraying to repel and control the incidence of yam beetle was based on how short the chemical persist in the environment after application. Hence the choice of Lambda cyhalothrin which persist for a week or less after application (from the manufacturer's instruction on the label). Beside, the frequency of spraying was decided based on the fact that the Lambda cyhalothrin is a short persistent insecticide coupled with the fact that the period coincide with frequent raining days which does not allow the chemical to stay longer after application.

Other good agronomic practices the farmers were trained on and implemented at the demonstrations sites included staking, early weed management and earthing up. The yam enterprise farmers were made to understand that staking the yam vines exposes the leaves to sunlight which increases the rate of photosynthesis and also prevents diseases caused by soil-borne pathogens. It was revealed during the first FFS session that farmers cultivate large acreages of yam and other food crops. They however concentrate on the other food crops, particularly maize, leaving their yam farms weedy. This often reduces the productivity of yam. They were therefore educated on the importance of early weed management as a means of preventing competition, weeds compete with crops and serve as alternate host to many insect pests and diseases.

Ensuring good field sanitation was also emphasized since it leads to increased yam productivity and quality of the yam tubers. The farmers were trained in how to monitor the invasion and activities of yam tuber beetles, which pose a serious threat to yam cultivation in the district. They were also told to earthing up the yam mounds to prevent the yam tuber beetles easy access into the mounds and also maintains high soil moisture in the mounds. The farmers were advised to check erosion on their fields since it exposes the developing yam tubers and thereby predispose them to beetle attack. Kusi *et al*. (2013) stated that the combined effects of the pre-planting and post sprouting treatments coupled with other good agricultural practices such as site selection, good land preparation, early planting at recommended spacing, effective weed management and staking contributed to the high tuber yield.

The farmers were then made to understand that this is all what IPM meant, thus, the use of multiple techniques in a coordinated program to maintain pest populations below levels that cause economic injury while also minimizing negative side effects.

Mini-sett Technology
The quantity of yam setts produced by the enterprise yam farmers from the use of mini-sett technology and the economic analysis is presented in Table 1. The quantity produced ranged between 1,500 setts and 4,000 setts from an area of a quarter of an acre or less. Out of the total of 30 farmers who initially expressed their willingness to adopt the mini-sett technology to produce yam setts, eight of them successfully produced commercial quantities of yam setts. When the estimated income was matched with their cost of production, the benefit cost ratio (BCR) showed an average of GHC3.0 gain on every one Cedi invested.

The same IPM approach was used to guide selected enterprise farmers who had earlier received some training in yam mini-sett technology and were willing to adopt the mini-sett technology as a business. Here, the project played a facilitating role to help them to raise yam setts for themselves and supply to other farmers in the community as a way to help ameliorate the unavailability and high cost of yam setts in the district at planting. The facilitation role of the project involved monitoring their mini-sett production activities, identifying their technical challenges, providing technical back stopping and assisting them to know where to obtain certain recommended inputs.

The variation in the yields recorded among the 8 farmers who used the technology to produce yam setts in commercial quantities could be attributed to the level of adoption of the technical advice provided by the project team. Those who followed the good practices recorded higher percentage sprouting and survival of the mini-setts planted. The technology that also caused significant change in their production is the pre-sprouting of the setts prior to planting. This ensured that only mini-setts that had initiated sprouting were planted. This led to higher percentage of plant establishment. The use of nylon ropes to trail the yam vines enhanced crop performance. Participant farmers were highly motivated by the economic analysis that showed the mini-sett technology as very profitable.

Storage structure
The improved structure was constructed with materials available in the communities with the exception of roofing sheets (Fig 7). The improved storage structure with fence made of roofing sheets completely eliminated incidence and damage by rodents. The thatch roof also prevented rain water from entering the structure and therefore reduced rotting of stored yam

tubers and setts. The shelf-life of the stored yam tubers and yam setts was extended up to seven months.

The farmers' storage structure constructed with thatch is presented in Fig.8. The farmers' storage structure is prone to rodent attack; the roof does not prevent rain water from entering the structure. This leads to high incidence of tuber rots, making it difficult to store yam tubers and setts in a healthy condition beyond three months.
Just as in the field production, the yam enterprise farmers were trained in good harvesting practices and postharvest handling that could extend the shelf-life of yam during storage. The farmers were advised not to delay harvesting of their yam to avoid predispose them to insect infestation on the field. Delayed harvesting may coincide with the dry season which makes harvesting difficult due to soil compaction. They were also advised to be careful not to wound the tubers and to cure them before storage in order to prevent them from rotting. Other good postharvest practices disseminated to the farmers were careful handling of yam tubers to prevent bruises and damages and storing the yam tubers on woven thatch to prevent contact with the bare soil as well as removal of sprouts during storage.

The improved storage structure maintains a cool micro-climate which is very good for storing yam tubers for long periods and also prevent rains from getting to the stored yam. The roofing sheet prevent rodents from entering the storage structure, protects farmers against reptiles particularly snakes and scorpions. The fence made of roofing sheets could also prevent bushfires from burning down the storage structure.

Conclusion
The successful implementation of the project and the impact it has had in yam setts and tubers production as well as extending shelf life of yam could largely be attributed to the integrated approach the project adopted. The participatory approach used in the dissemination of the proven technologist and production strategist to the farmers will also greatly enhance adoption among the farmers. This can therefore serve as a model to guide development and implementation of future projects in order to help the farmers and other stakeholders derive maximum benefits from research and development. It is also recommended that CSIR-TDTC provide further support for these technologies to be up-scaled to other enterprise farmers in other major yam producing communities in Ghana.

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Fig. 1: widely spaced mounds by farmers of approximately 2 mx 2 m apart.

Fig. 2: closely spaced mounds at 1.2 m x 1.2 m apart.

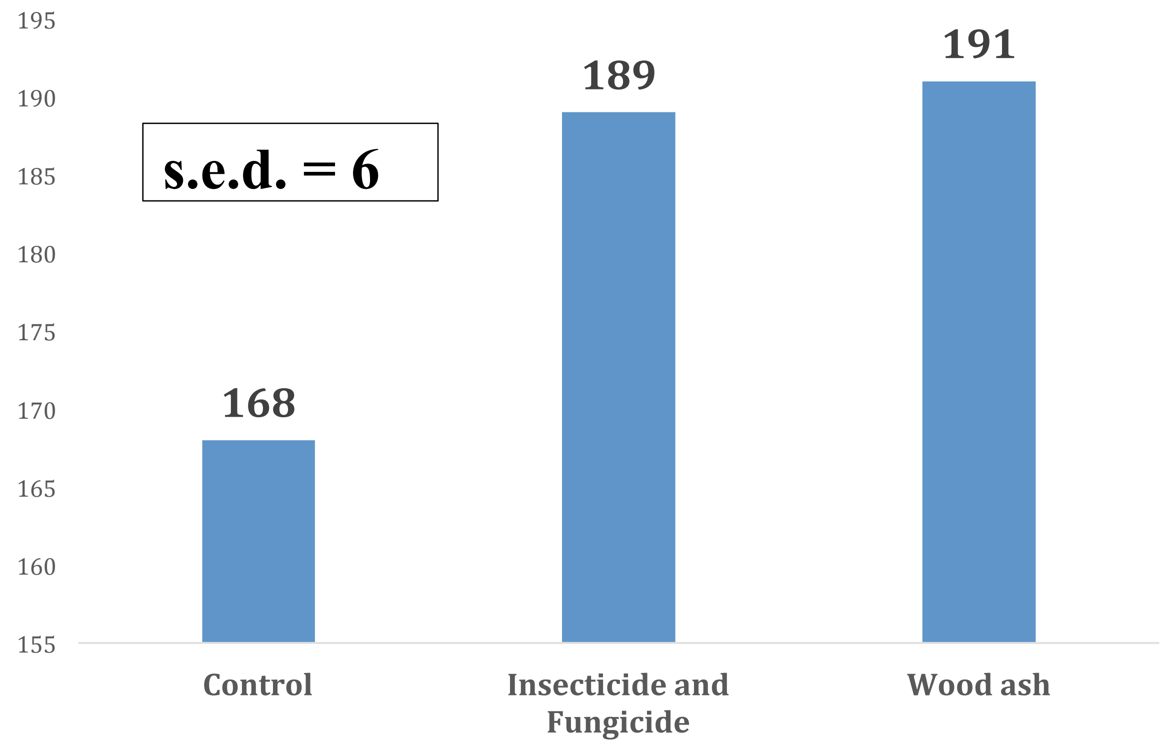

Fig. 3. No. sprouted setts 8 weeks after Planting

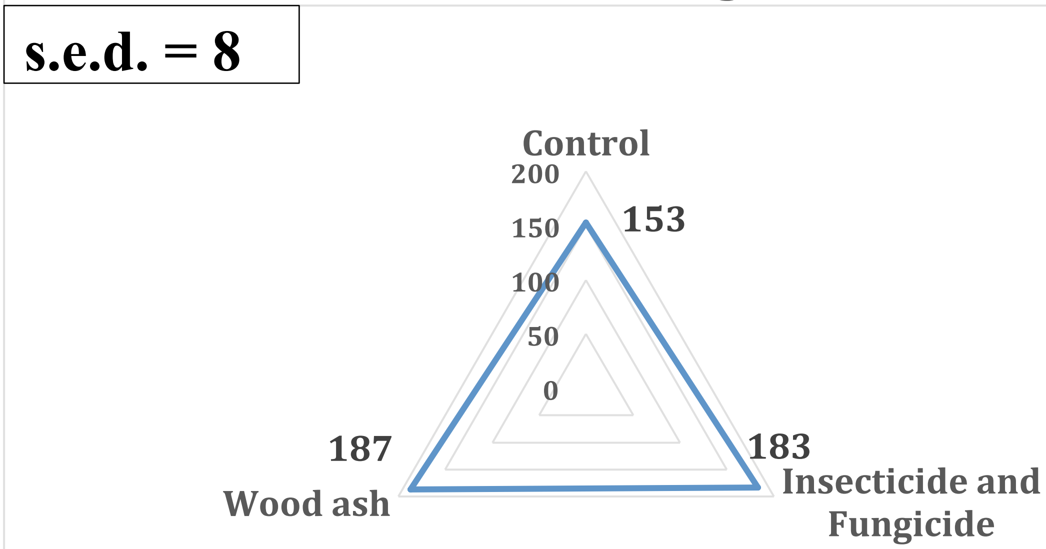

Fig. 4. Number of plants at harvest

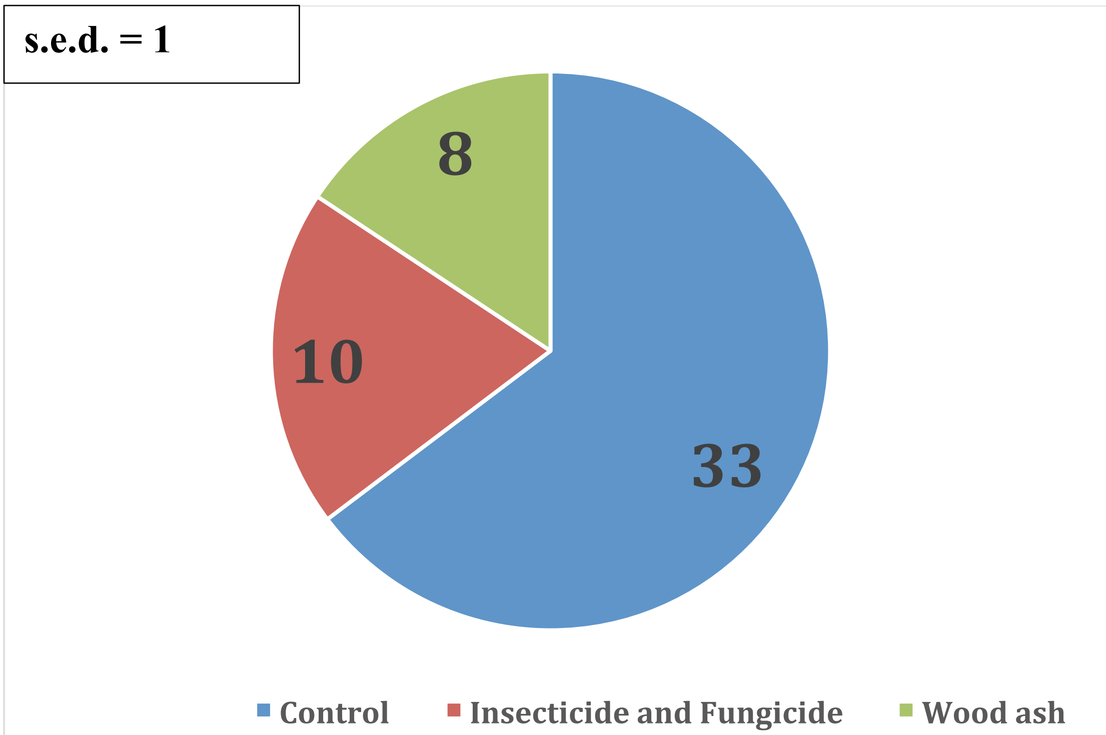

Fig. 5. Tubers with beetle damage

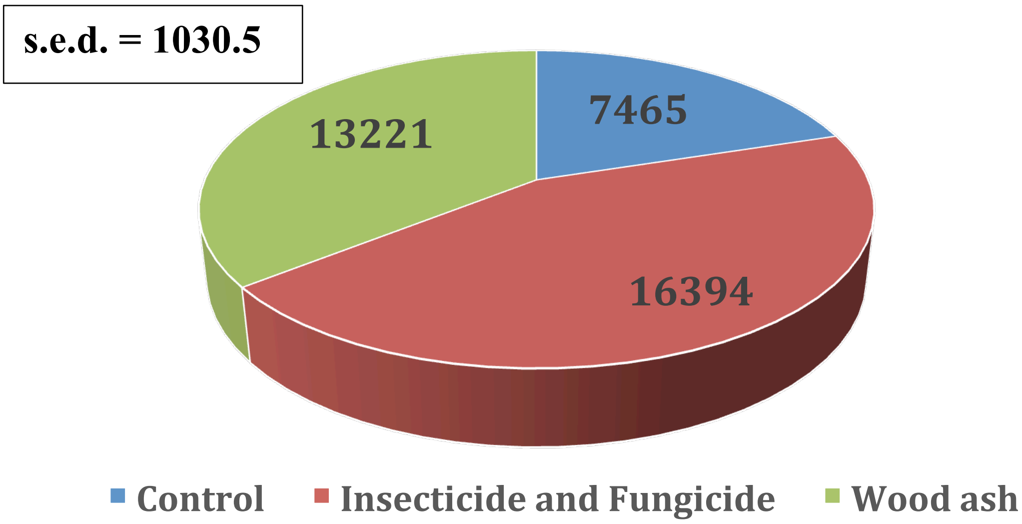

Fig. 6. Yam tuber yield/ha (Kg)

Table 1. Quantity of yam setts produced with the mini sett technology and economic analysis

Name of Farmer	Location	Quantity produced	Cost/100 setts at planting	Income generated	Cost of production	BCR
Alhassan Shiabu	Salankpang	4000	80	3200	1000	3.2
Alabani Mahammah	Salankpang	3500	80	2800	1000	2.8
Yakubu Fuseine	Salankpang	2500	80	2000	700	2.9
Issah Alhassan	Salankpang	2500	80	2000	720	2.8
Adam Musa	Kulinkpegu No. 1	1500	80	1200	400	3.0
Fuseine Yahaya	Kulinkpegu No. 1	2600	80	2080	790	2.6
Mahammadu Shiabu	Kulinkpegu No. 2	3000	80	2400	800	3.0
Mumuni Nindo	Kulinkpegu No. 2	3000	80	2400	800	3.0

Fig.7. Improved storage structure fenced with roofing sheets to eliminate rodents. The thatch roof also prevents rain water from entering the structure

Fig.8. Farmers storage structure prone to rodent attack, roof does not prevent rain water from entering the structure leading to high incidence of tuber rots

Development of innovative construction material from co-fired clay and rice husk in Ghana

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Abstract

Over the years, human survival on earth has created environmental burden emanating from waste generation. The burden of waste generation has attracted the attention of researchers, engineers and scientist to utilize waste generated by man into a more innovative material. The construction industry is among the industries in the world that embraces the utilization of innovative materials. In this work rice husk, a waste material was used as a major component in clay. Rice husk was used to replace clay at 1%, 1.5% and 2% by weight and co-fired at 800ºC. The co-fired materials were evaluated by testing the pozzolanic activity indices. The maximum pozzolanic activity index of the co-fired material was used to replace Portland cement at 10, 20, 30 and 40 wt.% to determine the optimum cement replacement using compressive strength test. The results indicated that co-fired material that contained 2 wt.% of the rice husk gave the maximum pozzolanic activity index. The optimum co-fired material that replaced cement was at 30 wt.%. The results show that innovative construction material could be produced from co-fired clay and rice husk and utilized to optimize Portland cement for the construction industry in Ghana.

Introduction

Human consumption of earth natural resources and the demand for goods and services to meet its survival is a major contributor to huge amount of waste generation and disposal into the environment (Sukholthaman and Shirahada, 2015). Waste quantities grows annually and this increase is attributed to rapid economic development and urbanization of society. The generation of wastes impose economic, social and environmental costs on society for its collection, treatment and disposal. The increasing waste along with associated economic, social and environmental impacts has created the opportunity and the techniques to reduce waste substantially.

Waste generation from the rice industry increases annually in most West African countries including Ghana, Nigeria, Togo, etc. due to consumption from population growth (FAOSTAT, 2015). In 2012, rice production in Ghana was about 0.48MT, moved to 0.57MT in 2013 and 0.6MT in 2014 (FAOSTAT, 2015). Zerbino et al. (2011) have stated that on average a tonne of rice produced generates approximately 200kg of rice husk. Annually, approximately 0.15MT of rice husk is produced in Ghana. Disposal of rice biomass in most Western African countries is commonly done by open burning. Uncontrolled or poorly managed burning of rice husk pollutes air quality creating objectionable adverse impact on the environment and on public health and safety.

In some developed countries waste from rice cultivation is not seen as waste but as a useful resource for the construction industry. Rice husk ash are usually processed and used as a pozzolan for the production of concrete and mortar (de Sensale, 2006; Zerbino et al, 2011). Rice husk has a calorific value between 16 and 17MJ/kg and could be used as biofuels. The ashes also contain amorphous silica which makes it among the highly reactive pozzolans. Clays can also be processed as a pozzolana. However, without heating at appropriate temperatures, pozzolanic properties cannot be activated. Using rice husk as a component in clay can serve as both a heating fuel and elemental silica that can further enrich the pozzolanic nature of clay. In this study the main objective is to develop a suitable cementitious material from co-fired clay and rice husk. The pozzolanic nature of the co-fired material was evaluated by testing the strength activity index whereas the optimum content of the material that was used to replace Portland cement was determined using compressive strength determination.

Problem Statement

The problem that this study sought to address is centered on two main issues and they are the environmental and economic issues. In the environmental sense, rice husk is a waste biomass which is usually disposed via open burning. Rice producing communities suffer from the burning of rice husk through air pollution (see Figure 1). From the economic point of view, the rice husk collection could bring about increase cost for town and city authorities. The cost of collection of waste is approximately \$10/tonne. Usually town folks are unwilling to pay for such cost and so in situations where city and town authorities become financially distressed, heaps of husk may be left unattended which also poses environmental nuisance.

Figure 1: Rice husk burning

Objective of the study

The main objective of this study is to produce a suitable pozzolanic material from co-fired clay and rice husk

Relevance of the research

The relevance of the research work is enumerated as follows:

1. The research work is intended to add value to biomass whilst reducing the environmental footprint of rice husk.
2. By adding value to biomass such as rice husk, there will be a window of opportunity for the treatment and disposal rice husk.
3. The success of this project will cause an expansion in the available alternative cementitious materials for construction

Literature Review

Calcined high grade kaolin clays also known as metakaolins have received considerable research with respect to their use as a supplementary material (Maia et al, 2014; Bich et al, 2009). However high grade kaolins are not abundant on the earth crust. Since high grade kaolins are of limited supply, they are very expensive and therefore researchers have focused attention on low grade kaolins which are very abundant on the earth crust. Calcined low grade clays have been proven to be a suitable pozzolanic material (Fernández et al. (2011); He et al., 1994; Maia et al. 2014). Kesse (1985) has shown data on available clay deposits in Ghana and this is depicted in Table 1

Table 1: Clay deposit in Ghana (Kesse, 1985)

Region	Tonnage(million)
Central	106
Greater Accra	200
Eastern	90
Western	742
Ashanti	39
Brong Ahafo	17
Volta	165
Northern	11
Upper East and West	22

Some ashes of biomass are considered to be good pozzolanic materials. Therefore, adding these biomasses to clay for pozzolan production can serve as a heating fuel source and elemental silica component to the calcined clay. Existing research works have little information on co-fired clay and biomass mixtures.

Materials and Methods

Materials

The materials that were used for the study included Portland cement, clay, water reducer, rice husk, sand and potable water. The Portland cement was an ASTM type 1/11 and was obtained from Ash grove, Kansas, United States. Clay was obtained from Nyamebekyere in the Ashanti region. Rice husk was obtained from a rice milling plant at Konongo in Ashanti region. Grade sand that conformed to ASTM C778 was used. A polycarboxylate high range water reducer obtained from BASF, United States was used. Table 2 presents the chemical compositions of the Portland cement.

Table 2: Properties of Portland cement

Property	ASTM Type I/II
Physical	
Fineness (m^2/kg)	401.7
Specific gravity	3.13
Chemical	
SiO_2 (%)	20.49
Al_2O_3 (%)	4.26
Fe_2O_3 (%)	3.14
CaO (%)	63.48
MgO (%)	2.11
SO_3 (%)	2.9
Na_2O+K_2O (%)	0.49
LOI (%)	2.2
Mineralogical	
C_3S (%)	56
C_2S (%)	15
C_3A (%)	6
C_4AF (%)	9

Methods

The clay was preconditioned by drying and milling in a hammer to sizes ranging between 75 microns and 2mm. the rice husk was used to replace clay at 2%, 1.5% and 1% and mixture used to formulate pellets of sizes ranging between 1 and 3mm. The pellets containing rice husk content of 2%, 1.5% and 1% were labelled as RH1, RH2 and RH3 respectively. The pellets were placed in a ceramic bowl of about 120mm and depth 90mm and calcined in a laboratory furnace at 800C for 3h. After the 3hrs, the ceramic bowl was removed from the furnace and left to cool on a metallic mesh under room temperature. The calcined materials were milled in a laboratory mill and sieved through the 75 microns sieve size using a mechanical sieve shaker.

Strength activity index (SAI) was determined by preparing mortar specimens in accordance with the ASTM C109 standards. The SAI determination was also guided by the ASTM C311 where replacement of cement is specified to be 20 wt%. The flow of the mortar specimens was determined in accordance with the activity index that gave the highest value was chosen and then subjected to incremental replacement of cement to achieve the optimum calcined material that could be used to replace Portland cement. The statistical analysis, both descriptive and inferential data were performed using excel data spread sheet.

Results and discussions

Figure 2 shows the strength activity indices of the control and the co-fired pozzolanic incorporated mortars. The ASTM C618 specifies that the activity of mortars containing pozzolans at 7 and 28 days must not fall below 75%. All the pozzolan mortars met the ASTM standard as indicated by the grey line. From the figure, all the co-fired materials attained mortar strength activity indices higher than the control. However, the maximum strength activity for all the mortars was RH1 (98% clay and 2% rice husk). The improvement of the strength activity index at RH1 could be attributed to the extra pozzolanic effect imparted on the calcined clay from the rice husk ash.

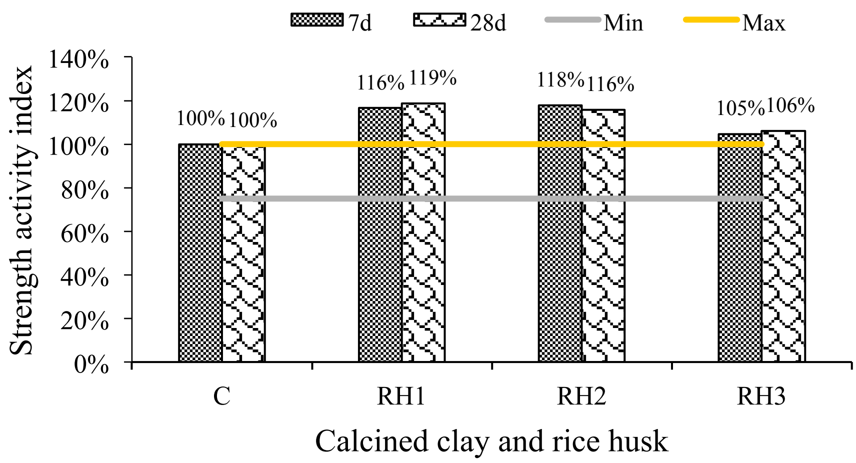

Figure 2: Strength activity index of co-fired materials

Figure 3 presents the results of the compressive strength of mortars containing the co-fired material that attained the highest strength activity index. The early age strength at 3 and 7 days of 10RH1, 20RH1 and 30RH1 were all higher than the control mortar except 40RH1. However, at 28 days, all the mortar mixture proportions attained compressive strengths which were higher than the control mortar.

Strength values between 20RH1 and 30RH1 were not statistically different therefore for optimization purpose, 30RH1 was fit for that. At higher supplementary cementitious content utilization, there are reduction in embodied energy and cost of the binder (Marceau et al., 2007).

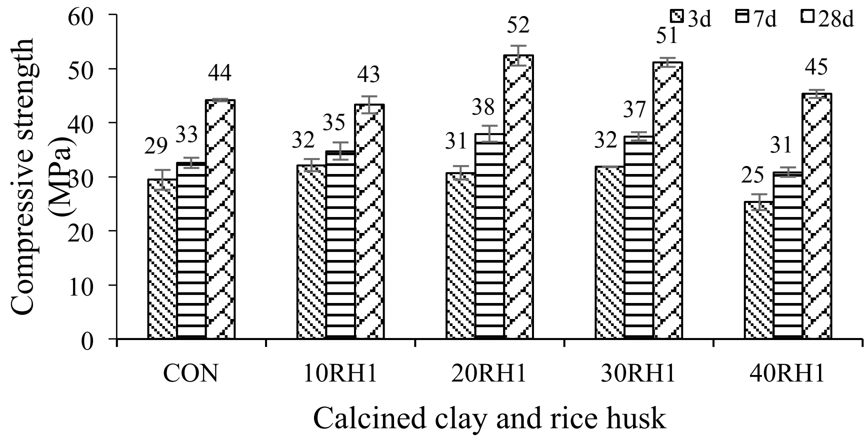

Figure 3: Compressive strength of mortars

Conclusions and Recommendations

Conclusions

The following conclusions are drawn from the study:

1. Co-fired material that contained 2% of rice husk content gave an optimum strength activity index

2. The optimum Portland cement replacement using the co-fired material was at 30%

3. For the Clay pozzolan industry, the rice husk biomass could be treated as useful resource. It does not compromise the pozzolanic nature of calcined clay

Recommendation

The recommendation made for the work was this:

1. The study must be expanded to investigate the serviceability of the material using standard durability testing methods and sustainability issues (TBL)

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THE ROLE OF POLICY AND MULTINATIONAL ENTERPRISES (MNES) IN GHANA'S AGRICULTURAL DEVELOPMENT: A CASE OF THE RICE INDUSTRY

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Abstract

A number of MNEs operate in the agricultural sector of Ghana playing different roles at every level of the agricultural value chain. Institutional and policy frameworks are important in promoting this. The focus of this paper is therefore to highlight some of the policy strategies guiding MNEs in Ghana and the agricultural sector as a whole. Furthermore, the study explores the role of MNEs in the rice value chain and finally discusses the outcome of the linkages of MNEs and local actors in the agricultural sector. The basic approach used in this study was desk research and secondary data from key institutions, through online repositories and technical reports from relevant organisations. Interviews with key informants also provided some information. The study identified the GIPC and MOFA as the key institutions guiding MNEs and the agricultural sector respectively, each with their specific policy and implementation frameworks. MNEs were identified along the entire rice value chain forming linkages with the actors. These linkages lead to the creation of market opportunities for the actors along the value chains; capacity building of farmers in best agricultural practices; and easy accessibility to inputs and local production techniques by the MNEs. The study recommends that the Government of Ghana should ensure that the investment climate in the agricultural sector is conducive and favourable in order to attract a lot of investors both locally and internationally.

Keywords: Policy, Multinational Enterprises, Ghana, Agricultural Development, Rice Industry

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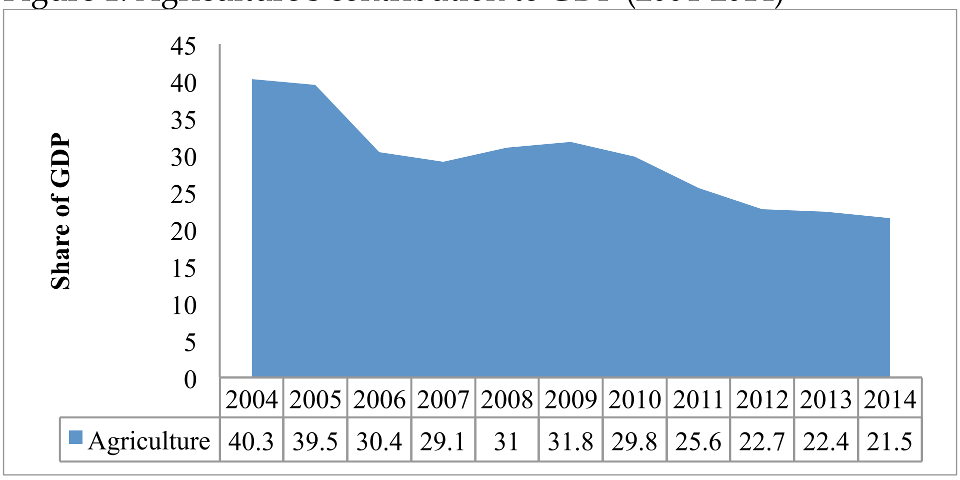
1.0 Introduction

Developing countries have a fundamental challenge of achieving socio-economic development to improve the quality of life of the populations. The UN Millennium Development Goals have come to represent the totality of the aspirations in development world-wide. Key actors in the development process include the private sector enterprises whose contribution to economic development in emerging economies cannot be underestimated. Private sector actors come in all kinds and sizes. However, a prominent category is the Multinational Enterprises (MNEs) whose business activities go beyond the boundaries of their respective home countries into other countries. Driven by the increasing globalization and the advancement in technology, MNEs operate world-wide including the developing countries with increasing ease. In this respect, the basic question is whether MNEs are making significant contributions to the attainment of the development goals of the countries they operate in. For a developing country like Ghana, this is an important question given its implication for development policy and the strategies for effective engagement with MNEs generally.

Agriculture dominates the Ghanaian economy contributing a third of total Gross Domestic Product (GDP) (ISSER, 2011). By virtue of its contribution to economic variables such as income generation, employment, food security, and export earnings, the agricultural sector is highly rated in Ghana. The agricultural sector is segmented into crops (cereals and starchy crops such as cassava, plantain and yam), livestock, fisheries, forestry and cocoa sub sectors. On one hand, positive growth rates within the agricultural sector come primarily from cocoa production and marketing. The livestock, fisheries, forestry and food crops subsectors, on the other hand, have not shown appreciable improvements in recent times; as the Forestry subsector even records negative growth rates (i.e. -14% and -1.4% in 2011 and 2012 (GSS, 2013) respectively).

The agricultural sector recorded a growth rate of 1.3%, in 2012 as compared to 7.0% and 10.2% in the industry and services sector respectively. In terms of contribution to the national GDP, the agricultural sector’s contribution has been decreasing over the years (ISSER, 2013). For example, between 2006 and 2012, its contribution has dropped from 30.4% to 22.7% whilst that of Industry and Services have been increasing ((ISSER, 2013).

Figure 1: Agriculture's contribution to GDP (2004-2014)



Source: ISSER (2015)

In 2014, the contribution of Agriculture to GDP was 21.5% which is about half of its contribution in the year 2004 as shown in Figure 1. However, irrespective of this decline in GDP contribution and slower growth rate, the agricultural sector still has a significant impact on employment and livelihoods over all the other sectors in the economy.

1.1 Challenges and Opportunities of the Agriculture Sector

The government and all key players in the agriculture sector admit that the sector is bedeviled with a lot of challenges and that hinder the growth of the sector. These challenges according to the Ministry of Food and Agriculture (2009) include the following:

- Poor human resource and management skills
- Poor natural resource management
- Food insecurity
- Poor infrastructural development (irrigation, roads, communication)
- Inadequate technological development and diffusion
- Poor market access

However, aside these challenges, there are a number of opportunities that can be harnessed for the development of the agriculture sector. Some of these key opportunities as cited by MOFA (2009) are directly linked to agricultural trade and they include the following:

- New foreign investments in horticulture and industrial crops
- Expansion of international trade in high-value commodities
- Activities to improve access to markets in the ECOWAS region
- Agreements between countries that give preferential access to international markets

From the opportunities listed, it is clear that the role of the private sector cannot be undermined and hence government has been encouraging Public Private Partnerships (PPP) over the years. Foreign Direct Investment (FDI) is also one key catalyst for the growth of the sector. There are a number of foreign enterprises; multinationals included who have their activities directed in the agricultural sector

In Ghana, there are a number of crops that have been targeted as investment crops; both staple and cash. Among the major staple crops produced in the country which includes maize, yam, plantain, cassava, sorghum, millet, rice plays an important role for subsistence and economic development of Ghana. More recently, rice has also received increased attention by consumers, hence producers have also responded positively in that direction. Investment opportunities exist in these staples as cassava, rice and maize have been identified as the three crops with short term investment opportunity (GOG, 2012). Rice production provides employment, income and food needs of millions of people in Ghana. Considering the population growth rate of 2.6% and the added competition from the industrial sector, rice production has been unable to meet domestic demand which exceeds 800,000MT annually with a deficit of about 500,000MT (Bam et al., 2013). The deficit has mainly been met through imports. It is estimated that the nation spends about 600 million US dollars ($) yearly out of her scarce foreign exchange on importation of rice from Vietnam, Thailand and other countries to mitigate the shortfall. The per capita rice consumption is about 45kg/year in Ghana and it is projected to increase by 9% per year on the average (Bam et al., 2013).

There are a number of MNEs operating in the three (3) main sectors of the economy, including the agricultural sector. These MNEs are located at every level of the agricultural value chain playing different roles, all contributing to the growth and development of the sector. This paper therefore highlights some of the policy strategies guiding MNEs in Ghana and the agricultural sector as a whole. It also discusses the role of MNEs in the rice value chain and finally discusses the outcome of the linkages of MNEs and local actors in the agricultural sector.

2.0 Methodology

The basic approach used in this study was desk research and the sourcing of secondary data from key institutions, through online repositories and technical reports from relevant organisations. Interviews with key informants also provided some information. The desk research involved reviewing of articles related to MNEs and the Rice Industry in Ghana.

The major sources of secondary data used in this report were the Food and Agriculture Organisation's Statistical website (FAOSTAT), the Statistics, Research and Information Directorate (SRID) of the Ministry of Food and Agriculture (MOFA) and the Ghana Investment Promotion Centre (GIPC). FAOSTAT and MOFA-SRID provided us with production, consumption and other quantitative data of rice in Ghana, whereas GIPC provided us with data on Foreign Direct Investment (FDI).

Both qualitative and quantitative data were gathered and data was analysed quantitatively using descriptive statistics and presented in charts. Qualitative analysis was equally carried out narratively.

3.0 Findings

3.1 Institutional Framework for MNEs Investment in Ghana

The Ghana Investment Promotion Centre (GIPC) was instituted in 1960 by His Excellency, the late Dr. Kwame Nkrumah as Capital Investment Board (CIB). The idea was to help Ghanaian entrepreneurs access capital in order to engage in any business that will help in the development of the country. However, in 1994, a law was passed and the name was changed to Ghana Investment Promotion Centre (GIPC) and was re-established by GIPC Act, 2013 (Act 865). This was (is) to encourage and promote investments in Ghana, to provide for the creation of an attractive incentive framework and a transparent, predictable and facilitating environment for investments in Ghana.

The objectives of the Centre are to; (a) Create an enhanced, transparent and responsive environment for investment and the development of the Ghanaian economy through investment; and (b) Encourage, promote and facilitate investment in the country. GIPC has it as a Vision, "to make Ghana the first destination of choice for investing in Africa.

In order to achieve the stated aims and objectives, the Centre performs the following functions:

- ✓ Formulate and implement investment promotion policies and plans, promotional incentives and marketing strategies to attract foreign and local investments in advanced technology industries and skill-intensive services which enjoy good export market prospects;
- ✓ Initiate and support measures that will enhance the investment climate in Ghana for both Ghanaian and non-Ghanaian enterprises;
- ✓ Initiate, organise and participate in promotional activities such as exhibitions, conferences and seminars for the stimulation of investments, to present Ghana as an ideal investment destination;
- ✓ Collect, collate, analyse and disseminate information about investment opportunities and sources of investment capital, incentives available to investors, the investment climate and advise upon request on the availability, choice or suitability of partners in joint venture projects;
- ✓ Register, monitor and keep records of all enterprises in Ghana;
- ✓ Register and keep records of all technology transfer agreements;
- ✓ Identify specific projects and prepare project profiles on investments and joint venture opportunities in Ghana and attract interested investors for participation in those projects;
- ✓ Bring about harmonization in investment policy formulation through coordination of the activities of all other institutions and agencies; and
- ✓ Perform any other functions that are necessary for the attainment of the object of Act 865

The Centre also offers certain services including the provision and dissemination of up-to-date information on incentives available to investors as well as assisting incoming and existing investors by providing support services including assistance to procure permits required for the establishment and operation of enterprises. GIPC operates in partnership with other existing government Ministries, Department and Agencies (MDAs). Some of the departments include the Bank of Ghana, Ministry of Trade and Industry, (MOTI), Registrar General's Department, Environmental Protection Agency, Ghana Chamber of Commerce and Industry, Ghana Export Promotion Council, among others.

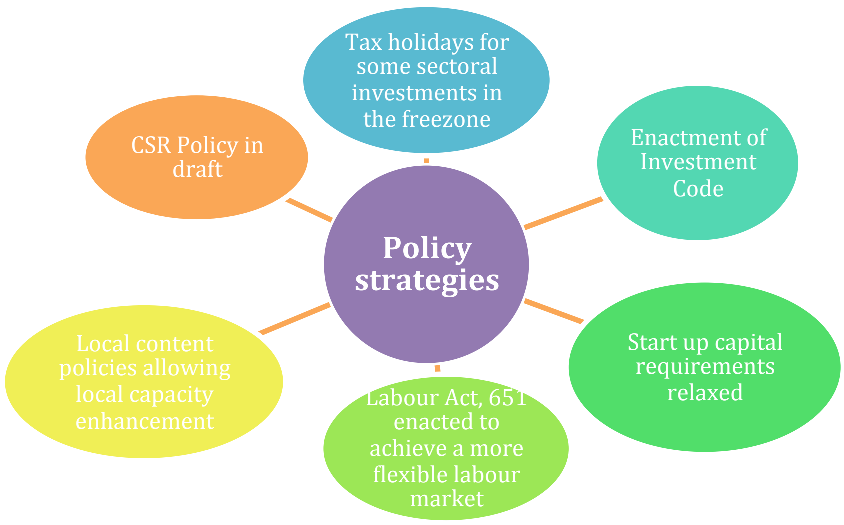


Figure 2: Policy strategies in attracting MNE investments

Some of the incentives to attract MNEs include tax holidays for trade and cash crop production and a zero corporate tax for manufacturing firms that invests in the three Northern regions of the country. Despite the incentives given to MNEs, the institute encounters some challenges in implementing the policies. For instance, an MNE may abuse a particular incentive by liquidating at the end of an incentive term and start off as a new company in order to enjoy another term of incentive. The Centre has set up the Investor Service Division (ISD) to provide what is termed 'After Care'. They play a role in helping the investors to have access to land, electricity and probably educating the community on the benefits they will derive if the investment is carried out in their area. There is the Monitoring and Evaluation Department whose activities are to ensure the smooth operation of the MNEs approved by GIPC.

3.2 Policy initiatives in the agricultural sector

The Ministry of Food and Agriculture is the main ministry responsible for developing and promoting agricultural development in Ghana. The overall goal of the Ministry of Food and Agriculture (MOFA) is to create an enabling environment for sustainable growth and development in the agricultural sector that would ensure:

- Food and raw material security
- Higher employment
- Reduction in poverty and the creation of wealth
- Greater contribution of the sector to GDP, foreign exchange earnings and government revenues

A number of policies and programmes have been formulated to enable the ministry achieve this goal and that which will also help Ghana realise her agricultural potential.

The Ministry of Food and Agriculture has a number of policy initiatives driving the agricultural sector. These policies are almost always in line with global as well as regional policy frameworks that ensures that the development of Ghana's agricultural sector is in sync with the development regionally as well as globally. Regional frameworks such as the Comprehensive African Agricultural Development Programme (CAADP) framework and the United Nations Millennium Development Goals (MDGs)-now SDGs are what form the building blocks of the policies. There are two main policy and implementation frameworks that drive the development and investments in the agricultural sector. These are the Food and Agriculture Sector Development Policy II (FASDEP II) and the Medium Term Agricultural Sector Investment Programme (METASIP).

FASDEP is one of the Ministry's response to provide a holistic approach to the agricultural sector taking cognisance of all ongoing efforts in the sector. It is the strategic framework through which all on-going and future projects and programmes will operate (MOFA, 2007). FASDEP emphasises the sustainable utilization of all resources and commercialisation of activities in the sector with market-driven growth in mind. It however targets fewer commodities for food security and income diversification, especially of resource poor farmers. Enhancement of productivity of the commodity value chain, through the application of science and technology, with environmental sustainability is emphasised. Greater engagement of the private sector and collaboration with other partners will be pursued to facilitate implementation of policies (MOFA, 2007). It can therefore be deduced that the key policy framework guiding the agricultural sector recognises the key role of the private sector, development partners and here; multinational corporations who are active private sector players in implementing agricultural growth strategies.

The Medium Term Agricultural Sector Investment Plan (METASIP) on the other hand was developed as a guideline to the achievement of the FASDEP. Currently, it is the most important document through which all indicators are measured. It was developed using a largely participatory process based on FASDEP II objectives with a target for agriculture sector GDP growth of at least 6% annually and government expenditure allocation of at least 10% of the national budget within the plan period. These targets are in conformity with agricultural performance targets of the country's National Development Planning Commission (NDPC), the Regional Agricultural Policy for West Africa (ECOWAP) of ECOWAS and the Comprehensive Africa Agriculture Development Programme (CAADP) of NEPAD and were expected to contribute significantly to the achievement of the United Nations MDGs. For an investment in the agricultural sector, these two policy documents are important to guide investment by MNEs.

Many a times, policy makers have been bashed for enacting policies with no implementation plan. However, same cannot be said of the case of the Ministry of Food and Agriculture with its METASIP framework.

METASIP places a lot of emphasis on agro-processing and advocates that it will be promoted through support to individual and group initiatives aimed at adding value to major food staples. The framework gives priority to the following crops:

- Maize (milling and packaging);
- Rice (milling and packaging)
- Cassava (gari, flour, etc),
- Yam (flour),
- Cowpea (grading and packaging), among others.

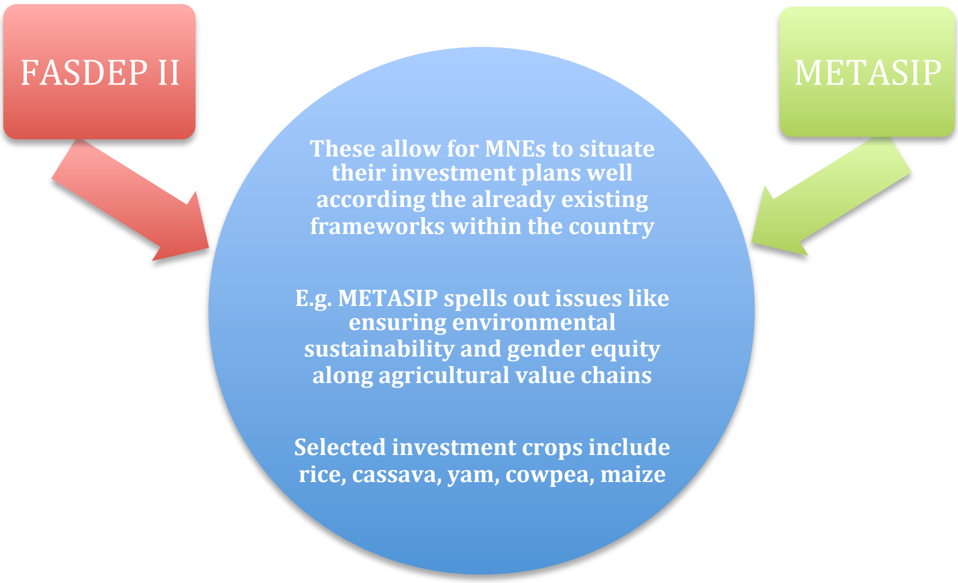


Figure 3: Key Policy and Policy Implementation Framework in the Agricultural sector

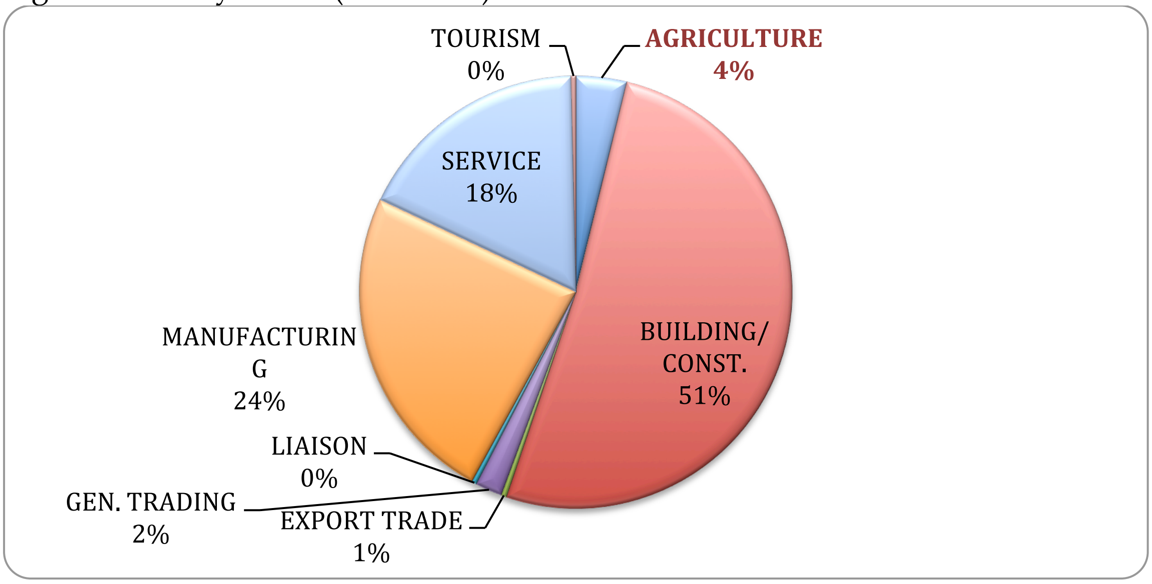
The support includes targeted training in value addition and linkages with relevant service providers and markets. According to the policy document, the use of appropriate grades and standards will be emphasised to improve quality, market penetration and reduce post-harvest losses. In promoting agro-processing, it has also been mentioned that care will be taken to ensure that the activities are carried out in an environmentally safe and sustainable manner. Thus all agro-processing interventions will be required to put in place environmental mitigation measures. Emphasis on gender equity has also been stated in the document in all activities along the value chain to ensure that the disadvantaged, especially women and youth play a major role in all activities. The Women in Agricultural Development directorate (WIAD) is spotted to be playing a leading role in these initiatives.

The two policy frameworks discussed above therefore provides a guiding framework for investors, both locally and internationally as to which areas to target and plan their investment activities. METASIP for instance place emphasis on some selected key investment crops which include rice, cassava, yam, cowpea and maize. In the conduct of their investment activity, environmental sustainability must be kept a par which is also clearly spelt out in the policy framework.

3.3 MNEs and FDI Contribution by Sector

There are multinational and other foreign enterprises in almost all sectors of the Ghanaian economy namely agriculture, industry, services and all other private economic activities that do not produce material goods[5]. Data from the Ghana Investment Promotion Centre (GIPC) shows that about one-third of all FDI flow into Ghana in the last decade has been registered in the manufacturing sector. The construction sector has also attracted a lot of MNEs especially in large scale construction of roads, dams, stadia and other giants infrastructural projects get underway. MNEs are seen to possess over 70 percent of mining concerns in Ghana. Figure 2.2 confirms the Building and construction sector receiving the most FDI in Ghana and the least being Tourism.

Figure 4: FDI by sector (1993-2013)



Data Source: GIPC, 2014

There have not been so much foreign investments in the agricultural sector as it is to other sectors in the past two decades. As shown in Figure 4, only 4% of the total FDI received have gone to the agricultural sector with a huge majority going into industry (Building/construction and manufacturing). It is agreeable that the country wants to build its industrial base, hence attracting more investments in the sector. However, the agricultural sector has been the backbone of the economy for years and it cannot be relegated to the background. Thus, there is the need for an equal attention in developing and attracting investments to the sector as it is given to other sectors recently. In relation to the goal of poverty reduction where most of the poor people are economically engaged, this is even more important.

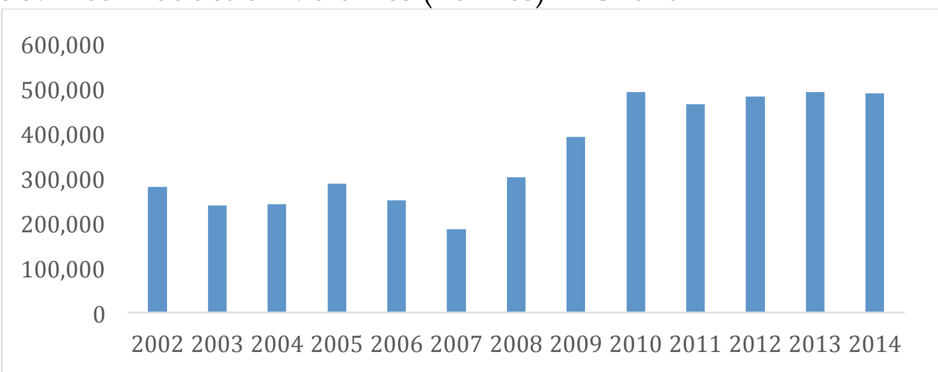
[5] By definition, agriculture includes farming, fishing and forestry. Industry on the other hand includes mining, manufacturing, energy production, and construction, while services cover government activities, communications, tourism transportation, finance, and all other private economic activities that do not produce material goods

With the limited FDI in the agricultural sector, India is the biggest investor in the agricultural sector accounting for a total of 76% of the FDI. The second agricultural investor is the USA with 12% of its FDI to the agricultural sector. Germany, Japan, Pakistan, Canada and Indonesia have less than a percentage contribution in the agricultural sector. It is however obvious that of the key sectors in the economy, agriculture receives the least investment by MNEs.

3.4 The Rice Value Chain and the Role of MNEs and Local Actors

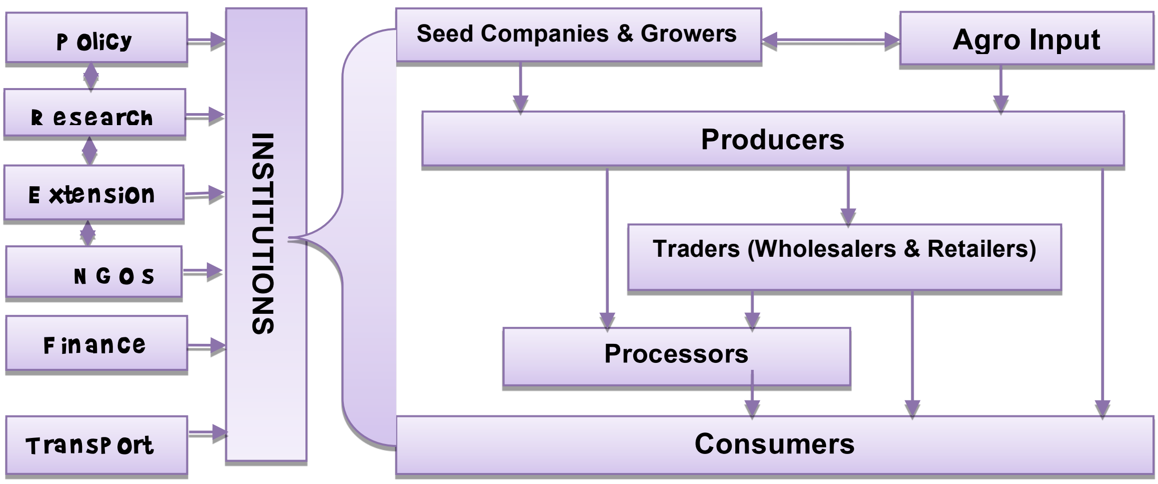
According to an Oxford Business Group (OBG) report in 2013, Ghana's rice sector has been under scrutiny in recent years, and the government has been working to reduce its agricultural imports by boosting the level of domestic production. The private sector has been seen to be playing key roles in this regard and a number of state-led initiatives aimed at improving production have been rolled up by the government. The Ministry of Food and Agriculture (MoFA) projects a doubling of rice production by 2018 under a programme dubbed, the National Rice Development Strategy (NRDS), instituted in 2009. Among other goals, the NRDS seeks to improve land and water management practices, improve access to government services and also to establish partnerships with the private sector (OBG, 2013).

Figure 5: Rice Production Volumes (Tonnes) in Ghana



Data source: FAOSTAT (2015)

The Rice Value Chain



Source: Adapted from SARI (2013)

The main actors within the rice value chain in Ghana are the input suppliers who are mainly agrochemical seed suppliers; producers (both small scale and large scale); processors (small and large scale) and distributors (wholesalers and retailers).

Input supply chain

The major types of input suppliers within the rice value chain are the seed suppliers and agrochemical input dealers. In Ghana, farmers usually source seed for planting either from their previous harvest or from the Ministry of Food and Agriculture (MOFA) and local seed dealers. The government of Ghana is also making investments and improving access to technology for local farmers. Under the Agriculture Machine Subsidy Programme, rice combine harvesters were made available at Agricultural Mechanisation Service Centres (AMSECs) across 64 districts, with training provided to 400 operators. The Ministry of Food and Agriculture has provided 50 rice threshers to small-scale rice farms at its network of AMSECs. MNEs were not identified at this level of the value chain. However, Nestle Ghana was seen to be playing a role through capacity building of local farmers to produce good quality rice.

Production chain

There are a number of government initiatives supported by Development Partners such as the Africa Development Bank (AfDB), Alliance for a Green Revolution Africa (AGRA), Agence Francaise de Development (AFD), AVCO, Africa Rice Center; and MNEs such Global Agri-Development Company (GADCO) and Nasia Rice. In April 2013 an American multi-national, AVCO Agriculture Company acquired 500 ha of land in the Volta Region for rice cultivation. A seed investment of $500,000 is to be made in the project in the next three to five years (2016-2018). The objective of the company is to make Ghana become the primary source of food security in the Sub-Saharan region. Realizing the high demand for rice consumption in Ghana, the company seeks to break through the market by reducing the importation of rice into the country. This investment will go a long way to increase the level of rice production in the Volta region, which will inherently increase the country's domestic rice production level (GNA, 2013).

The Ministry of Food and Agriculture in collaboration with Agence Francaise de Development (AFD) of France has implemented a project called Rice Sector Support Project, established in 2008. This project is in line with MOFA's strategy to facilitate the production of food crops to attain food self-sufficiency, output processing and marketing systems. The project supports lowland rice production of up to 6,000 hectares in the Northern, Upper East, Upper West Regions and northern parts of the Volta Region of Ghana. By the project completion date a total of 16,250 metric tons of milled rice would be produced annually to add to the existing production (MOFA, 2014).

Another outfit, Global Agri-Development Company (GADCO), signed a 30-year lease in 2011 on 1000 ha of land to develop high-quality rice crops. GADCO, which was established with the input of Brazilian agriculture experts, produces two annual harvests over 1600 ha of land, and plants new paddies each month. The company has made an initial investment of $15m in its first phase of the project (OBG, 2012).

Prairie Volta Ltd, a registered corporation owned 30% by the Government of Ghana (GoG), 30% by Ghana Commercial Bank (GCB), and 40% Prairie Texas Inc (PT) an American corporation also has a rice project in the Volta region of Ghana. This is a typical example of the Public Private Partnership approach the Government of Ghana is promoting to foster growth and development in the agricultural sector. The corporation has been involved in large scale rice production and processing in the country since its inception in 2008 (Anderson, 2011).

Processing

The Volta and Northern regions of Ghana have well established commercial rice processing enterprises, which are located within or near irrigation schemes. All post-harvest activities such as threshing, cleaning, de-husking, de-stoning, polishing, drying, winnowing, milling and packaging are performed at the processing sites at a mechanized level. This leads to the production of paddy of higher quality [medium quality (>5% - 25% broken) to premium quality (<5% broken)] compared to manually processed rice (Bam et al., 2013).

Multinational Enterprises including Prairie Texas Inculcated (Prairie Volta in Ghana), Brazil Agro Investment, Avnash, GADCO, Nasia rice, AVCO and Nestle (see Figure 4.7) perform activities in the rice processing chain in Ghana. In Ghana rice is processed as parboiled rice, brown rice, white rice and rice flour. Nestle Ghana process rice into flour in the form of various products ranging from baby foods to adult foods.

Nasia Rice Company is owned by a consortium of banks namely Barclays, National Investment and Agricultural Development Banks. Nasia Rice Company installed a mill in 1977. The mill however stopped operations between 1997 and 2008. However in 2009, the mill was reactivated by the shareholders and processed rice for the National Food and Buffer Company (NAFCO). NAFCO also buy grains and store for national emergencies.

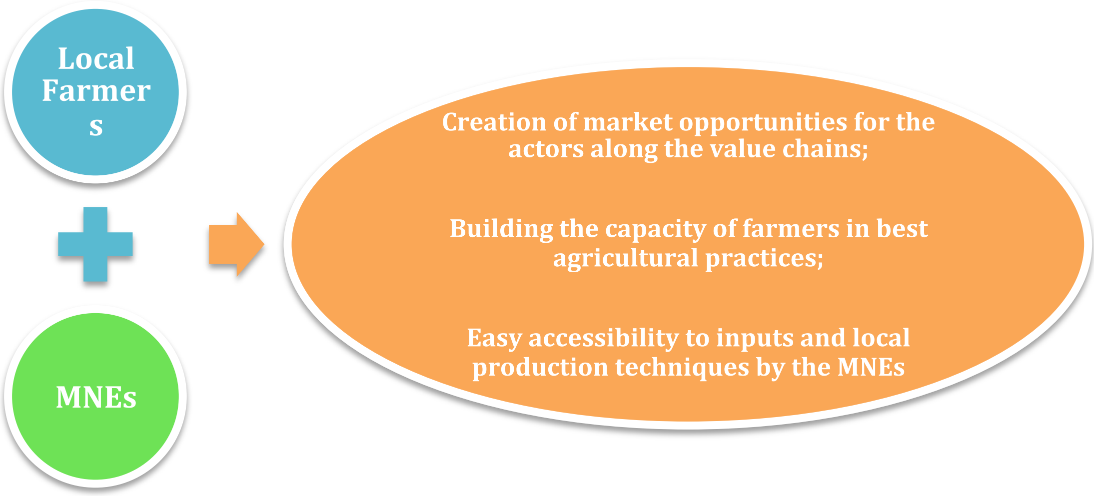
Prairie Volta Ltd established in 1998 is owned by Government of Ghana (30% shares), Ghana Commercial Bank (30% shares) and Prairie Texas Inc. (40% shares). Brazil Agro Investments is also a 100% privately owned company. Private and Foreign investments is crucial for the processing chain as highly and quality processed products have higher margins compared to raw products. Higher gains could however be made from the rice industry if processing is given the maximum attention and hence a call to all investors to direct their efforts to this stage in the rice value chain.

Distribution (Marketing)
In terms of marketing, there are two major supply chains in Ghana. The first is the local rice supply chain and secondly, the imported rice supply chain. Both supply chains are fairly simple, although that of the imported rice is quiet shorter and assumed to be more efficient as compared to the local supply chain (Angelucci et al., 2013). Trade liberalization has also played a significant role in creating the current structure of the rice market. From government regulation and distribution in the pre-liberalisation period, there now exists a host of private traders distributing and determining the price of rice through supply and demand from the farm gate to urban consumers in the local rice supply chain; and/or from the country's ports to consumers in the hinterland along the imported rice supply chain (Amikuzuno et. al., 2013). There are a number of privately owned and MNEs who are involved in large scale distribution and marketing of rice. However, these entities are only involved in distribution and marketing of imported rice. These are Royal Bow Company Ltd., Continental Commodity Trade Company (CCTC), Cereal Investment Co. Gh. Ltd, Olam, and Ezal Trading Gh. Ltd. Importers directly distribute to wholesalers all over the country and often sell rice on a credit basis. Wholesalers have a distribution network of retailers who in turn sell to consumers in either large bags of 50kg or in accepted units known as olonka[6] or margarine tins (CARD, 2010).

The local rice supply chain involves a host of indigenous rice millers/processors and itinerary wholesalers and retailers operating between the largely smallholder farmers and the final consumer. From the itinerant and traders, the commodity may either be distributed directly to final consumers, or may be further distributed through different levels of retailing and restaurants before the final consumer. In other instances, some local processors who have well established distribution networks can also act as small scale wholesalers (Angelucci et al., 2013). To meet their cash needs, about 94% smallholder rice farmers begin selling their produce after harvesting to small scale indigenous, processors/millers, who are usually individual women or women associations (Amikuzuno et al., 2013). Some traders in urban and other markets in Ghana often participate in the two supply chains simultaneously by selling both local and imported rice (Amikuzuno et al., 2013).

3.5 Outcome of MNEs and Local Actors Linkages
The creation of linkages between MNEs and local actors have bi-dimensional impact. The first is the impact it has on the local actors through knowledge transfer opportunities and opening up of market opportunities. On the other hand, the MNEs can benefit from such linkages by taking advantage of local production technologies and access to local inputs.

[6] Medium size measuring tin, measuring about a kilo



These linkages allow local actors to be productive and enable MNEs adapt to local conditions and reduce cost of production. There is also the creation of market opportunities for the local firms. This could subsequently increase their turnovers, leading to increased incomes and hence reduction in poverty. It could also create job opportunities resulting from these local enterprises employing more staff to be able to meet the demands of these MNEs they have formed linkages with.

One of the MNEs that is making a huge impact in Ghana's agriculture include Nestlé Ghana and. As the world's biggest food and beverage company, Nestlé relies on millions of farmers around the world to supply agricultural raw materials needed for its products. These farmers and farm workers are essential to the ongoing success of the company. Nestle Ghana has collaborated with local programmes such as the Northern Rural Growth Programme, the Ministry of Food and the International Institute of Tropical

Agriculture (IITA) to develop training programme to help farmers increase the quality of cereals, in particular maize and millet, used to produce Cerelac (infant cereal). More than 50,000 farmers, including 24,000 women, 1,200 agriculture extension officers, have been trained on field and in 'classroom type' activities on how to address the challenges poor grain quality in.

Conclusion

It is in no doubt that the private sector has been playing a key role in the development of the agricultural sector in Ghana which inherently has an impact on the achievement of the MDGs, especially those related to agriculture. The investment climate of the nation has improved as a result of government opening up its collaboration with foreign investors. The agricultural sector though has been declining in its contribution to the nation's GDP, it still observes a positive growth which is a potential for greater achievements. There are a number of MNEs along the rice value chain and there are equally existing institutional and policy frameworks that allow these MNEs operate. Key among the institutions is the GIPC and MOFA (with their FASDEP and METASIP policy strategies).

Rice, though not a traditional staple has received a lot of attention over the years as demand continues to rise and hence there are investments geared towards the sector by various multinational enterprises, other private sectors and the government as well. The key multinational enterprises identified within the rice value chain are Nestle Ghana, Praire Texas Inc., Brazil Agro Investment, Nasia Rice Company, Olam Ghana, Global Agri-Development Company, AVCO and Ningxia Agricultural Development Group. All these MNEs play key roles along the rice value chain. Whilst some are along the entire value chain, others have specific stage of the value chain that their activities are directed towards. The linkage formed between the MNEs and local agricultural actors had led to the creation of new market opportunities for the local actors; capacity building of the local actors by adopting best agricultural practices of the MNEs; and finally the MNEs benefiting from the local actors by having easy access to local inputs and adapting to local practices.

The development of the agricultural value chains is key to the country's growth and development and hence the government of Ghana needs to ensure that the investment climate in the agricultural sector is conducive and favourable in order to attract a lot of investors both local and international. Without harnessing the support of the world's great MNEs, the UN's Sustainable Development Goals especially those related to poverty and hunger will be difficult to attain.

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PART 4: ENHANCING THE MANUFACTURING SECTOR THROUGH PRODUCT INNOVATION

PERCEIVED RISKS AND BENEFITS OF GENETICALLY MODIFIED FOODS: PERCEPTION OF STUDENTS OF THE UNIVERSITY OF GHANA, LEGON

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Abstract

In spite of its benefits in improving crop yield and others, concerns about potential health risks and safety of the environment have taken a center stage debate in public policy and discourses on biotechnology emergence and applications in food and feed productions. This study employed across sectional survey, to explore perception of selected university students on the perceived health effects (benefits and risks) of genetically modified organisms (GMOs) and Genetically Modified Foods (GMFs). The results indicate that while 63% of the respondents perceived GMFs as harmful to health, the remaining 37% indicated that GMFs were not harmful. The results also showed a statistically significant association between 'heard of GMO/GMF' and environmental impacts as well as acceptability of GMFs and environmental impacts. This study therefore shows that despite the many discussions on the technology, there are still those (even at higher levels of learning) with mixed feelings about the technology. As mentioned elsewhere, among others, the sources of information, interest, knowledge and trust levels in the technology explain the differences. It is suggested that education and awareness creation on the technology need to be improved at all levels.

Keywords: Genetically Modified Food Technology, Genetically Modified Foods, Biotechnology

1.0 Introduction

This paper looks at the public debate on the public acceptability of genetically modified organism and feeds in relations to risks to human health and safety of the environment as a way of informing the public and policy about spurring informed discussion on the subject and technology. The case of selected students of the University of Ghana was explored.

1.1 Background

One important defining element of any new technology in terms of acceptability or otherwise is the benefits it offers over and above those existing. This observation however, does ignore the fact that benefits and beneficiary groups of the technology may vary and that opposition may arise to challenge general acceptance of the new technology -Biotechnology. This technology has been hailed as one of the major scientific and technological revolution in the 21st century and therefore touted as having the potential to change society's ways of production and wellbeing of people. Advocates view its emergence as one of the major scientific and technological revolution that is happening in the 21st century. These technologies promises to have that which fundamentally can change society's organisation, production and distribution of food (Hallman, Hebden, Aquino, & Cuite, 2003). Some potential benefits of the technology to the society include reduction of hunger and malnutrition and the prevention and cure of diseases (Isserman, 2001;UNDP, 2001). These are achieved through improvement in agricultural productions and the pharmaceutical industries (Malcolm & Sinnett, 2015).

As seen in emerging technologies, the public associates both benefits and risks with technological processes applied to food production (Frewer, Shepherd, & Sparks, 1994). Advocates believe that Genetically Modified (GM) products have inherent capacity not only to meet basic need, but to also bring to bear the wide range of economic, environment and health benefits. They also accentuate the potential benefits to society through promotion of health and general well-being (Isserman, 2001; Fukuda-Parr & Birdsall, 2001; FAO, 2014). A study conducted in southwestern zone of Nigeria among scientists from nine universities in the Agriculture and Biological sciences faculty, reported 45% of the scientists agreeing that GMFs with higher contents of digestible iron are beneficial to consumers. On the other hand there are perceptions that food containing biotechnologically engineered ingredients represents more threat at the societal level than at the individual level (Frewer et al., 2002). While some opponents of GMFs may agree that genetically modified crops produce better yields, they stress its devastating risks to human health, safety and the environment (Buah, 2011). Of these people, some claim potential threat caused by genetically modified foods is the creation of new allergies or harmful toxin that may cause sickness or death to vulnerable populations (Buah, 2011).

The developed and western countries have received extensive attention through the publication of articles and writing of books: (Rimal, Moon, &Balasubramanian, 2005; Kamaldeen, 2002; Morris &Adley, 2000; Morris &

Adley, 2000; Bonny, 2003; Hallman et al., 2003; Ganiere, Wen & Chern, 2004; Curtis, McCluskey, & Wahl, 2004; Gaskell, 2000; Moon & Balasubramanian, 2003), conferences (Sophia & Powell, 2000; Hollingworth& Meade, 2003) and the study of social implications and public concerns about biotechnology (Gaps et al., 2000; Blaine, Kamaldeen, 2002). However, the consuming publics in the developing countries are left in the state of uncertainty. Little investigation has been conducted in developing countries such as Ghana, where the technology is not yet practiced on a large scale (Anderson,Wachenheim & Lesch 2005). African countries and for that matter Ghana is emerging as frontline in the confusion for acceptance or otherwise of agricultural biotechnology. Significantly, this discussion is occurring at a period when food insecurity, poverty and malnutrition, among other antidevelopment issues, are particularly increasing. This study sought to find out the perceived health benefits and risks of genetically modified foods among University of Ghana students.

Methods

Design and study Sites

The study employed a quantitative study approach. The study design was a cross-sectional survey, using a structured questionnaire. The study site was the University of Ghana, Legon campus, which operated on a collegiate system.

Study population, exclusion and inclusion criteria

The study population was made of all students of the University of Ghana, main campus, Legon. The estimated number of undergraduates and postgraduates was 30,000. The study involved male and female students who were 18 years and above and registered students of the university. The study excluded lecturers and other permanent or temporal staff of the University. This study population was selected because, as an educational institution, the respondents were expected to be knowledgeable about the study topic.

Sample size and sampling

The sample size used in the study was 194 students. The sample size was calculated using Epi info. The student population was estimated at 30,000. Based on an expected frequency of 85%, 95% confidence level and a design effect of 1.0, the total sample size was calculated to be 218 with 10% non-response rate included. Stratified convenience sampling technique was employed in this study. An average of 50 students was selected from each of four categories the entire population of students based on colleges.

Data collection technique and pretest

This study adopted the use of structured questionnaires with both open and close-ended questions which included the demographic information of the participants, their knowledge on GMO's and their perceived effects on health. The questionnaire was developed based on the objectives of the study and reviewed literature. Due to the literacy of the population, questionnaire was self-administered. Data collected on the questionnaire were double checked for completeness. Incomplete responses were returned to the respondents to be filled appropriately. Respondents who lost interest in the study were replaced. Questionnaires with missing information were excluded from the analysis.

Data was entered into an excel spreadsheet and exported into IBM SPSS Statistics version 20 for Windows for analysis. Double data entry and cleaning was done to reduce data entry errors and validate authenticity. The questionnaire was pre-tested on 20 students from the Central University College, Accra. This choice was preferred because it shared certain similar socio-demographic features with the University of Ghana students. The pretest allowed a few modifications to certain complex questions for clearer understanding for the actual study respondents.

Variables

This study assessed the perceived health risks and benefits of genetically modified foods among the students of the University of Ghana. The perceived health risks and benefits were the dependent variables. The explanatory variables were evaluated in the bivariate analysis of the study. The variables include:

Sociodemographic characteristics

- Age
- Sex
- Marital status
- Religion
- Level of education

Knowledge of GMF

- Heard of GMO/GMF
- Understanding of GMF
- Sources of information
- Availability of GMFs in Ghana

Perceived health benefits and risk of GMF

- Consumption of GMF
- Perceived health benefits
- Perceived health risks

Other perception of GMF

- Acceptability of GMF
- Environmental impact

Data Analysis

Statistical analysis of the data sets collected were performed using IBM SPSS Statistics for Windows version 20.0.Variables that were categorized included age, understanding of GMFs, health risks and health benefits. Participants view on GMFs in terms of consumption were dichotomised into being harmful or not harmful. The responses for the benefits and risks of the GMFs were categorized under reoccurring themes provided by the study participants. The reoccurring themes for the benefits were denoted as follows: 1.00 denoted nutritional concerns; 2.00 denoted disease resistant crop resulting in high yields; 3.00 denoted improved health of humans as a result of immunity and 4.00 was used to represent no idea, no response and not sure. These beneficial outcomes were further dichotomized into being a variable named beneficial or not beneficial (respondents who stated no response, no idea and not sure). Beneficial was denoted as 1.00, while not beneficial 2.00. A similar thing was done for the health risks. Reoccurring themes were coded as 1.00 for allergy and allergic reactions; 2.00 for cancer; 3.00 for other related diseases such as stroke, high blood pressure; 4 for no response, not sure and no idea. The risks were further dichotomized into either being risky 1.00 or not risky2.00 (not risky denoted respondents who stated no response, no idea and not sure)

The level of knowledge of the study respondents was measured based on the following set of questions; whether a respondent has heard of GMOs and GMFs, the interest of the respondent on GMOs and GMFs issues, the idea about GM Technology (GMT) and what genetically modified foods are. The overall awareness level was examined using 4 questions. With the maximum accumulated score of 9, respondents who scored 0 to 3were classified as low knowledge level, those who scored 4 to 6 were categorized as moderate knowledge and those who scored 7 to 9 were classified as high knowledge. Radio, television, newspaper and internet were categorized as media. The ages of respondents were categorized according to the standard age classification by WHO. Respondents views on genetically modified foods in terms of consumption were dichotomized into a variable named harmful or not harmful. The responses given by study participants regarding the perceived health risks and benefits were recoded under recurring themes.

Univariate analysis was used to generate descriptive tabulations for the explanatory variables. The background and socio-demographic variables were grouped under socio-demographic characteristics. The understanding, sources of information, availability and ever heard of GMF were grouped under knowledge of GMFs. Similarly, the consumption, perceived health risks and benefits were also grouped under perception of GMFs, Perceived health benefits and risk of GMF. Acceptability and the environmental impact of GMF were represented under other perception of GMF. Bivariate analysis was carried out to examine the associations between the effects of the consumption of genetically modified foods and the explanatory variables. Pearson chi-square statistics were used to determine explanatory variables that were statistically significant. P-value < 0.05 was used to denote statistical significance.

Limitations of the study

The study relied on self-reported information from the respondents. Information given by the respondents could not be verified, therefore there may be an information bias.

RESULTS

Table 1 presents the background and socio-demographic characteristics of the respondents. A little over fifty percent of the sampled respondents were males (51 %). More than half of the respondents were between the ages of 20 and 24 years. Majority of the respondents were reported to be single (86.1%). Almost all the respondents were Christians (93.2%). Evaluating the levels of education, most of the study participants (74.2%) were undergraduates, while 25.8% were postgraduate students.

Table 1: Social Demographics of Study Respondents

Characteristic	*Frequency (N=194)*	*Percentage (%)*
Sex		
Male	99	51
Female	95	49
Age (years)		
18-19	19	9.8
20-24	115	59.3
25-29	22	11.3
30-34	15	7.7
35-39	11	5.7
40-44	7	3.6
44-49	5	2.6
Marital		
Single	167	86.1
Married	27	13.9
Religion		
Christian	181	93.3
Muslim	13	6.7
Educational level		
Undergraduate	144	74.2
Postgraduate	50	25.8
TOTAL	**194**	**100**

Knowledge of GMFs

Knowledge of GMFs among the study respondents was measured based on whether a respondent have heard of GMOs, the availability and acceptability of GMFs in Ghana, what genetically modified foods mean and the sources of the information. The result of the study revealed that most of study respondents (92.8%) have ever heard of the term GMOs/GMFs. Majority of the study participants understood what GMF and its technology meant with one-quarter of the study participants having moderate meaning of GMFs. only 1% had a low understanding of the term. The assessed view on the availability of genetically modified foods in Ghana also revealed that, majority of the study participants (72%) believed GMFs are present in Ghana while 28% believed they cannot be found in Ghana.

Table 2: Knowledge of GMFs

Characteristic	Frequency (N=194)	Percentage (%)
Heard of GMOs/GMFs		
Yes	180	92.8
No	14	7.2
Understanding of GMOs/GMFs		
High	143	73.7
Moderate	49	25.3
Low	2	1.0
Availability of GMFs in Ghana		
Yes	140	72.2
No	54	27.8
TOTAL	194	100

Sources of information on GMF
The study participants listed radio and television as the most common source of information on genetically modified foods. The media including radio, television, internet and newspaper were the most common source of information while books, among others were recorded as the less common sources of information

Source	Frequency	Percentage (%)
Radio	110	56.7
Television	112	57.5
Internet	86	44.3
Newspaper	61	31.4
Books	32	16.5
Lecturer	17	8.8
Friend	64	33.0
Others	8	4.1

Total is more than 100% because multiple responses were required.
Others include other family members, talk sessions.

Perceptions about GMFs
Table 3 shows the perceived risks and benefits assessed by the study participants. The view of the study participants on the consumption of genetically modified foods revealed that, more than half, (62.9%) believed it to be harmful while 37.1% believed it not to be harmful. Despite the number of participants that perceived GMFs to be harmful, 37.6% of the study participants opted to accept the use of genetically modified foods when it is comparatively cheaper. The results of the study show that, more than half (62.9%) of the participants perceived that the official introduction of genetically modified foods will cause harm rather than good to individuals living in Ghana. About 62.9% of the participants, perceived that the acceptance of the technology in Ghana, will increase the risk of Ghanaians to cancer (40.8%), other related diseases (17.0%) and allergies (5.8%). However,

concerning health benefits associated with GMFs, only 45.4% of the study participants believed the use of the technology can be beneficial to Ghanaians. More than half of the participants had no idea of the benefits to be derived from the use of the technology. About 33.0% believed that, the use of the technology and consumption of its outcomes has the potential to address all nutritional related problems. Albeit, high yield has no direct correlation with health, 5.2% of the study respondents indicated high yield as one of the health benefits of GMFs.

Table 3: Perceived Health Risks & Benefits and other perceptions

Characteristics	Frequency (N)	Percentage (%)
Consumption of GMF		
Harmful to health	122	62.9
Not harmful health	72	37.1
Health Risks		
Allergy & Allergic Reactions	12	5.8
Cancer	84	40.8
Inflammation of the liver	5	2.4
[1]Other related diseases	35	17.0
No response/not sure/no idea	70	34.0
TOTAL	206	100
Health Benefits		
[2]Address nutritional concerns	65	33.0
Vaccine	5	2.5
[3]Others	16	8.2
High Yield	5	2.5
No response/not sure/no idea	106	53.8
TOTAL	197	100
Other perception of GMFs		
Acceptability of GMF		
Yes will accept	73	37.6
No, will not accept	73	37.6
Not sure	48	24.7
Environmental Impact		
Positive	46	23.7
Negative	73	37.6
Not sure	75	38.7
Total	**194**	**100**

[1] *Other related diseases include: Stunted growth, infertility, stroke and other related heart disorders, diabetes, antibioticresistance, genetic mutation, unknown long term effects, deformity at birth, infertility, and chemical related diseases.*

[2]*Addressing nutritional concerns includes, addressing malnutrition issues, enhancing the nutrient content of foods (rice with enhanced vitamin A).*

Others indicated that some.

[3]*Others include the promotion of children's growth reduction of health risk, curing diabetes, food security among others.*

Perceived health risks and its association with explanatory variables

A bivariate level analysis was performed to examine the association between the explanatory variables and the perceived health risk as the first outcome. There was a statistically significant association between heard of GMO/GMFs and environmental impact at P > 0.05. There was no significant association between the other explanatory variables, although certain variables were seen to be statistically significant in previous studies. The female study participants (54.0%) who were comparatively more than the males (46.0%), believed that the use of GMF in the country's food production could presents risks to human health. Study participants with high understanding of GMFs (75.8%) also perceived certain health risks to be associated with the use of GMFs.

Table 4: Association of perceived health risks with explanatory variables

	Outcome n (%)		Chi square	P – value
	124 (63.9%)	70 (36.1%)		
Characteristics	Risky	Not sure/no response		
Sex				
Male	57 (46.0)	38 (54.3)	4.762	0.575
Female	67 (54.0)	32 (45.7)		
Age (years)				
18-19	11 (8.9)	8 (11.4)	1.239	0.168
20-24	76 (61.3)	39 (55.7)		
25-29	17 (13.7)	5 (7.1)		
30-34	8 (6.5)	7 (10.0)		
35-39	6 (4.8)	5 (7.1)		
40-44	3 (2.4)	4 (5.7)		
44-49	3 (2.4)	2 (2.9)		
Marital				
Single	109 (87.9)	58 (82.9)	0.951	0.222
Married	15 (12.1)	12 (17.1)		
Religion				
Christian	116 (93.5)	65 (92.9)	0.034	0.535
Muslim	8 (6.5)	5 (7.1)		
Educational level				
Undergraduate	92 (74.2)	52 (74.3)	0.000	0.565
Postgraduate	32 (25.8)	18 (25.7)		
Heard of GMOs/GMFs				
Yes	120 (96.8)	60 (65.7)	8.174	0.006
No	4 (3.2)	10 (14.3)		
Understanding of GMOs/GMFs				
High	94 (75.8)	49 (70)	2.309	0.550
Moderate	28 (22.6)	21 (30.0)		
Low	2 (1.6)	0 (0.0)		
Availability of GMFs in Ghana				
Yes	94 (75.8)	24 (34.3)	2.269	0.091
No	30 (24.2)	46 (65.7)		
Other perception of GMFs				
Acceptability of GMF				
Yes will accept	42 (33.9)	31 (44.3)	5.139	0.777
No, will not accept	54 (43.5)	19 (27.1)		
Not sure	28 (22.6)	20 (28.6)		
Environmental Impact				
Positive	57 (46.0)	16 (22.9)	10.538	0.005
Negative	27 (21.8)	19 (27.1)		
Not sure	40 (32.3)	35 (50.0)		

Perceived health benefits and its association with explanatory variables

As done with the perceived risks, there was a statistically significant association between Acceptability of GMF and environmental impact at $p < 0.005$. However, there was no association between age, sex, level of education, and understanding of GMFs although such explanatory variables were seen to be statistically significant in previous studies. Less than half of the study participants perceived that the use of GMFs could be beneficial to human health.

Table5: Association of perceived health benefits with explanatory characteristics

	Outcome n (%)		Chi square	P – value
	88 (45.4%)	106 (54.6%)		
Characteristics	Beneficial	Not sure/no response		
Sex				
Male	41 (46.6)	54 (50.9)	0.365	0.323
Female	47 (53.4)	52 (49.1)		
Age (years)				
18-19	9 (10.2)	10 (9.4)	4.016	0.675
20-24	49 (55.7)	66 (62.3)		
25-29	12 (13.6)	10 (9.4)		
30-34	9 (10.2)	6 (5.7)		
35-39	4 (4.5)	7 (6.6)		
40-44	2 (2.3)	5 (4.7)		
44-49	3 (3.4)	2 (1.9)		
Marital				
Single	78 (88.6)	89 (84.0)	0.877	0.234
Married	10 (11.4)	17 (16.0)		
Religion				
Christian	79 (89.8)	102 (96.2)	3.203	0.067
Muslim	9 (10.2	4 (3.8)		
Educational level				
Undergraduate	67 (76.1)	77 (72.6)	0.307	0.349
Postgraduate	21 (23.9)	29 (27.4)		
Heard of GMOs/GMFs				
Yes	86 (97.9)	94 (88.7)	5.879	0.013
No	2 (2.3)	12 (11.3)		
Understanding of GMOs/GMFs				
High	69 (78.4)	74 (69.8)	3.000	0.223
Moderate	19 (21.6)	30 (28.3)		
Low	0 (0.0)	2 (1.9)		
Availability of GMFs in Ghana				
Yes	60 (75.0)	74 (69.8)	0.644	0.261
No	22 (25.0)	32 (30.2)		
Other perception of GMFs				
Acceptability of GMF				
Yes will accept	50 (56.5)	23 (21.7)	25.389	0.000
No, will not accept	51 (25.0)	51 (48.1)		
Not sure	16 (18.2)	32 (30.2)		
Environmental Impact				
Positive	37 (42.0)	9 (8.5)	35.518	0.000
Negative	18 (20.5)	55 (51.9)		
Not sure	33 (37.5)	42 (39.6)		

Discussion

Knowledge of GMFs

Overall 93% of participants claimed to have heard of GMFs. The result of this study was comparatively high compared to previous studies in the country. Deffor (2014) asserts in a survey conducted in Accra Metropolitan Assembly, Ga East and Tema Metropolitan Assembly using purposive sampling, that about 90% of the respondents had heard something about genetically modified foods and the awareness level was high. Amin, Azlan, Hamdan, Samian, & Haron (2011)who conducted survey among the Malaysia public from August 2009 till February 2010 using self-constructed multidimensional instrument measuring ethical perception of transgenic banana; Prokop, Lešková, Kubiatko, & Diran (2007) survey among the Slovakian university students and Demirci, (2008) study among the Turkish geography teachers showed high level of awareness of genetically modified foods. The findings here contrast with a study conducted in Nairobi at three points of sale (supermarkets, kiosks, and posho mills) where only 38% of the study participants were aware of genetically modified crops and foods (Kimenju, De Groote, Karugia, Mbogoh, & Poland, 2005).This disparity could be because 58.3% of the study respondents in the Kenyan study were below the university level of education as compared to the current study where all the study participants were university students; pursuing either first degree or postgraduate degree and for that matter they are academic imbibed and enlightened and can easily access information.

The high awareness of biotechnology and genetically modified foods among the University of Ghana students reflected in their knowledge about GMFs. The study results showed that, majority of the study participants (73.7%) had good knowledge about what GMFs meant and understood the application of technology. This agrees with a finding from a study conducted in Indonesia, where 70% of study participants had good knowledge about GMFs (Februhartanty, Widyastuti & Iswarawanti, 2007).This study identified the mass media (television, radio, internet and newspapers) as the main sources of information on biotechnology and GMFs. This confirms with findings from previous studies that showed that the main sources of information on biotechnology, GMO and GMFs is the media (Kimenju et al., 2005; Frewer et al., 2004; Curtis, McCluskey, & Wahl, 2004; and Tekedere, Taban & Çaliskan, 2011). The media has great influence on the public's awareness of GMFs. This could be inferred because, much time is spent watching television and listening to the radio as the major sources of entertainment and education. Therefore, the media has been identified as an important tool to disseminate health information (Haque, Arafat, Roy, Khan, Majbah Uddin, 2014).

Perceived Health Risks and benefits of GMFs

Generally, findings from this study showed that females perceived more risks in relation to GMFs effect on health and also to the application of (Genetically Modified Technology) GMT as compared to their male counterparts. This observation is in trend with National Science report which found that there is significant gender gap in attitude towards genetic modification, with female considerably more likely than men to believe that the risk outweighed the benefits (Blaine & Kamaldeen, 2002). Similarly, the findings of this study also showed that males were more likely to accept GMFs if they were cheaper as compared to females. However the findings is consistent with the hypothesis (Moerbeek & Casimir, 2005).

This study's findings are also supported by other studies (Buah, 2011; Moerbeek & Casimir, 2005; James & Burton, 2003; Anunda, Njoka, & Shauri, 2010) which detected difference in perception according to gender, mainly, females, had more negative attitude towards GMFs. In a related study, (Burton, Rigby, Young & James, 2001) concluded that females shoppers were willing to pay more premiums to avoid GMFs than males, suggesting less acceptability of GMFs among females. Moreover, studies have revealed that women perceive lower benefits and are less likely to accept GMT than men (Siegrist, Cvetkovich, & Roth, 2000; Costa-Font, Gil, & Traill, 2008). These results indicate that a significant divergence exists between men and women regarding their opinions about genetic modification of crops and foods. Since the study was made up of highly educated participants, therefore, the disparity between male and female attitude towards biotechnology and GMFs could not be explained by lack of knowledge of biotechnology. However, they may be explained by variation in trust, values and subjective norms. This implies that views and perception of gender with regards to GMOs and GMFs is very important to be considered in making informed decision for the public.

The implication of GMFs on health has become public health concern (Maghari & Ardekani, 2011). Out of the 194 study participants, 63% expressed their fears about the negative health effects associated with consuming genetically modified foods. They perceived that the acceptance of the technology in Ghana will increase the risk of Ghanaians to cancer, other related diseases and allergies. The findings of this study is consistent with an earlier study conducted by Kimenju et al., (2005), who stated that the core of the controversy over GM crops is the extent to which consumers perceive benefits from the technology relative to its risks. This could be argued that it was "misinformation' stirred up by activists aided by the media, which led the study respondents to view GMFs as harmful to health. There seems to be no established empirical evidence about the risk of GMFs in relation to health. This has led to much speculation about GMFs effect on health. This could also account for the negative perception of the study participants concerning GMFs. However, a significant percentage of the respondents (37.0) believed that consumption of GMFs is not harmful to health.

Study participants (33%) who perceived the consumption of GMFs to have positive effects on human health cited one of its advantages as addressing nutritional concerns, that is, improving the nutritional value of crops and foods. This observation compares with a study in Indonesia among agricultural scientists who found that 39% of the study participants, perceived the consumption of GMFs improved nutritional value of humans (Februhartanty et al., 2007). Although only 2.5% of the study participants perceived that the consumption of GMFs could act as a vaccine to infer immunity, it compared with Key, Ma, & Drake, (2008) study in South East Asia where GM potatoes were required to meet annual demand for hepatitis B vaccine.

Generally, the use of GMT to produce foods with enhanced nutrient was perceived by participants to have both potential benefits and risk. It showed that 51% of the study respondents' perceived the use of GM technology to produce food as risky while 49% believed it's useful. However, with regards to the use of GMT to make crops more resistant to pest and diseases; majority of the respondents (63.9%) believes that is very useful. Similarly, previous studies have shown more positive views towards GM when used as crop disease resistant as compared to food enhancement generally (McComas, Besley, & Steinhardt, 2014;Anunda, Njoka, & Shauri, 2010).

Regarding the environmental impact, the findings here corroborate with Sloan (2000) study. The previous study reported that consumers perceived organic food production as environmentally friendly, however using GMT in food production is perceived as less environmentally friendly and that consumers are unaware of the benefits that GM has on the environment (Siró, Kápolna, Kápolna, & Lugasi, 2008). It was revealed that participants who perceive GMOs has negative impact on the environment are much more concerned about the unknown effect on the environment.

Conclusion

In conclusion, the results revealed that while a large number of the students claimed to be aware or heard of the technology their judgment on risks and benefits seem divergent. This can particularly be attributed to their source of information on biotechnology. Biotechnology is a new science, which can properly be communicated well for better understanding by the scientists and technologists involved in the practice. However, the television, radio, newspapers and internet seem to be the key sources of information and not workshops and conferences populated usually by the technology expects who can do justice to the explanations of how the technology works, the benefits and risks. While the sources of information provided are critical in the dissemination of the information on the new technology, the credibility of those who write on the technology can be suspicious. Those sources may lack physical interaction for questions of clarification and better understanding of issues. As would be predicted by several models of diffusion, rejecting or judging a technology as high risk could be due to the absence of considerable information on the benefits of the technology. The latter could be as a result of less scientific and technical expertise and also funding to perform more research and disseminate information on local benefits of the new technology to the public and a more locally defined package.

As argued in another paper, the sources of information on such a sensitive subject and technology is critical, however, the trust, knowledge levels and interest of new technologies among social groups such as gender and age is significant in informing the scale of judgment. In all, the authors are of the view that providing information on GMFs by critical expertise will help improve people's knowledge and trust about GMFs, perceptions about the potential health outcomes of GMFs and in turn develop positive attitude towards GMFs. The implication therefore is that, policy-makers must consider the issue of GMFs and bring all appropriate stakeholders on board so as to discuss the way forward to make the right and appropriate GM policies.

List of Abbreviations

GM crops- Genetically Modified Crops

GM- Genetic Modification

GMFs- Genetically Modified Foods

GMOs-Genetically Modified Organisms

GMT-Genetic Modification Technology

ISAAA - International Service for the Acquisition of Agriculture-Biotechnology Applications

UNDP – United Nation Development Programme

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PRESERVATION OF MEAT AND FISH USING SOLAR-SCREENED DRYING TECHNIQUE

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Abstract

Solar or sun drying of meat products has been an age-old preservation method however it is bereft with several challenges that render the product unsafe. Scientists from CSIR-ARI explored the use of solar-screened drying technique to dry meat and fish products with the objective of reducing environmental contamination of the products. A portable solar-screened dryer constructed of Perspex was used to study the drying efficacy of meat and fish products. Beef muscle was sliced into thin film (about 2 cm), anchovies, and big fish sliced into halves were studied. The study revealed that drying in the solar-screened dryer required significantly less time (22 h) than direct sun drying, which could take several days). Losses due to vermin were also reduced in solar-screened dryer and the shelf-lives of the products were longer than products dried directly under the sun.

Introduction

Meat is important in the diet of man because it provides protein, which is needed for tissue growth and repairs of worn out tissues. According to Cudjoe (1986), meat provides sound nourishment for a significant proportion of the world's population despite outcries against the commitment of food grains to the production of meat animals whiles millions of humans in other parts of the world live with starvation.

In Ghana, the production of animal protein is rising. For instance, in 2002 meat production was reported to be 73,559 metric tons (MT). This increased steadily to 96,740MT, 105,772MT, 118,504MT, 135,412MT in 2007, 2009, 2011 and 2013 respectively (MoFA, 2013). However, not much is being done to develop and improve indigenous methods of meat preservation in order to ensure sustainability and food security. Post-harvest losses result due to management and technical limitations in processing, infrastructure, storage, etc. According to Njie (2012), worldwide annual post-harvest losses from meat alone amounts to US$7.19 billion; a situation that is very worrisome and requires interventions.

In most developing countries including Ghana, the most popular means of preservation include drying, smoking and refrigeration with smoking and drying being very indigenous. Developing effective preservation and

improving upon the known indigenous methods could go a long way to address losses and ensure food security especially among the rural folks.
Meat handling in Ghana is generally poor and this starts right from slaughter till it reaches the final consumer (Adzitey *et al.,* 2011). This leads to serious food safety and public health concerns while pre-disposing the meat to spoilage and loss of economic gains. This is particularly challenging for the rural poor who have to devise ways of keeping carcasses harvested from their farms. Although most homes in cities may have refrigeration, power supply is generally unreliable. Therefore, the need for alternate forms of preservation that is independent of electrical/gas power supply cannot be over-emphasized. FAO (1990) has reported that there is lack of effort to provide knowledge and skills in adequate hygiene, slaughtering, meat cutting and handling under rural conditions. This brings to the fore, the need to bridge the knowledge gap in terms of meat handling and preservation.

Due to its high protein and moisture content, meat is an ideal medium for bacterial growth (Warriss, 2010). Consequently, prompt application of preservation methods is critical in preventing the growth of both pathogenic and spoilage organisms. Processes in meat preservation principally focus on inhibiting microbial growth although modes of preservation which minimize contamination and depreciation of the quality of the commodity are sought. This involves application of measures to delay or prevent certain changes which make meat unusable as food or which degrade the quality aspect of food. The pathways by which such deterioration can occur are diverse and not only include microbes but also chemical and physical processes.

In fact, drying under environmental temperatures, humidity and air circulation with the assistance of sunshine is known to be the oldest method of meat preservation. It preserves meat by reducing the water activity i.e. free water excluding that bound to proteins. Unless there is enough moisture available, micro-organisms cannot grow. The minimum water activity for the normal growth of bacteria is 0.91; yeast, 0.88; mold, 0.80 and that for salt tolerant bacteria is 0.77 (Adams and Moss 2010). Therefore, water activity must be reduced below these critical levels for effective preservation. Drying involves the removal of moisture from the outer layers and the migration of moisture from the inside to the outside. Muscle meat of any kind can be dried but it is necessary to use thin and lean meat since fat becomes rancid upon drying. Traditionally, meat is sun dried under unhygienic conditions mainly in the open floor or roof tops and is exposed to grit, insects, rodents and other organisms thereby compromising its safety and wholesomeness. A study by Apata *et al.* (2013), indicated that open air sun drying of meat was not the best. Apart from exposure to contamination, open air sun drying also affected the chemical, yield and organoleptic properties of the product therefore development of different methods of drying meat is important for preserving meat without much damage to it.

The objective of the study was to determine the quality and wholesomeness of solar dried meat.

Materials and Methods

A solar-screened dryer was designed and fabricated. The dryer/cage had racks on which the meat was hanged for drying. The dryer was roofed and covered with transparent material sheets through which the sun reached the product. The plastic roof and stainless steel/glass side screens protected the meat from undesirable elements thereby ensuring the safety and wholesomeness of the product.

Fig. 1. Prototype Solar dryer

Meat and fish were purchased from a facility that was considered to handle these products in a hygienic manner. The meat and fish were sorted, cut, deboned and sliced into films of about 2 cm thick and washed in clean and salted water. They were drained, seasoned using the formulation in Table 1 and arranged on drying trays and set in the dryer. The meat and fish films were turned over every four hours to facility uniform drying. Fans were turned on to remove moist air in the dryer during the drying process.

Table 1. Percentage composition of ingredients used for seasoning meat and fish

Ingredient	% Composition
Nutmeg	10
Ginger	40
Garlic	30
White pepper	10
Rosemary	7.5
Salt	2.5
Total	100

Fresh and solar-screened dried meat and fish were tested for levels of microbial contamination. Total Viable Count (TVC) and Total Coliform Count (TCC) techniques were used and colonies were counted using the Plate Count Technique as number of colonies counted multiplied by the dilution factor expressed in cfu/g.

Ten grams of the samples were weighed aseptically into sterile plastic stomacher bags and macerated. A 1:10 dilution was prepared by adding 90 ml of phosphate-buffered saline (PBS, Oxoid Dulbecco ABR, UNIPATH, Basingstoke, England, pH 7.0).

The 1:10 suspension was thoroughly mixed and further ten-fold serial dilutions were carried out by aseptically transferring 1 ml of this into 9 ml of the diluent, and serially diluted in the same buffer solution, starting from 1:10 through 1:100,000. Half a milliliter volume of the dilutions was inoculated onto various agar plates and spread using sterile glass spreader. Cultures of microbes recovered were prepared using Blood agar and Mac Conkey agar to purify and isolate the microbes. Colonial morphology, cell morphology and biochemical reactions were used to isolate and identify the organisms as described by Agbodaze et al. (2005).

Fifty millilitre portions of 1:10 suspension was centrifuged at 10,000 rpm for 30 minutes in a refrigerated centrifuge (4°C). After decanting the supernatant, a loop-full of the pellet was streaked onto sheep blood agar and MacConkey and incubated at 37°C for 18–24 hours under aerobic condition. Gram method was used for preliminary identification of the isolates. The Gram method was complemented by standard biochemical test as described by Pamela et al. (1990). Plates which had between 30–300 colonies were selected for the determination of colony forming unit per gram (cfu/g). Bacterial isolates were suspended in PBS and fixed by adding 2 or 3 drops of 40% formaldehyde per 10 ml and mixed thoroughly by vortexing. Bacteria counts were carried out using colony counting chamber (Gallenkamp, UK). The number of cfu/g in the sample was calculated by multiplying the number of bacteria by the dilution factor (Agbodaze et al., 2005).

The duration of drying was between 18-35 hours depending on the sunshine intensity and duration as well as thickness and leanness of meat and fish films. The drying conditions, ambient and internal temperatures, relative humidity and wind speed were monitored using Almemo data logger. The dried product was tested for microbial safety and microbial load values were compared with that of the recommended levels by the Ghana Standard Authority (2013) (Table 2).

Table 2. Recommended microbial load for meat

Parameter	Minimum level, cfu/g	Maximum level, cfu/g	Lethal dose, cfu/g
Total viable Count	$\leq 10^3$	10^5	10^6
Mould and Yeast count	10^2	10^4	$\geq 10^5$

Source: Ghana Standard Authority (GS 955: 2013)

Results and Discussion

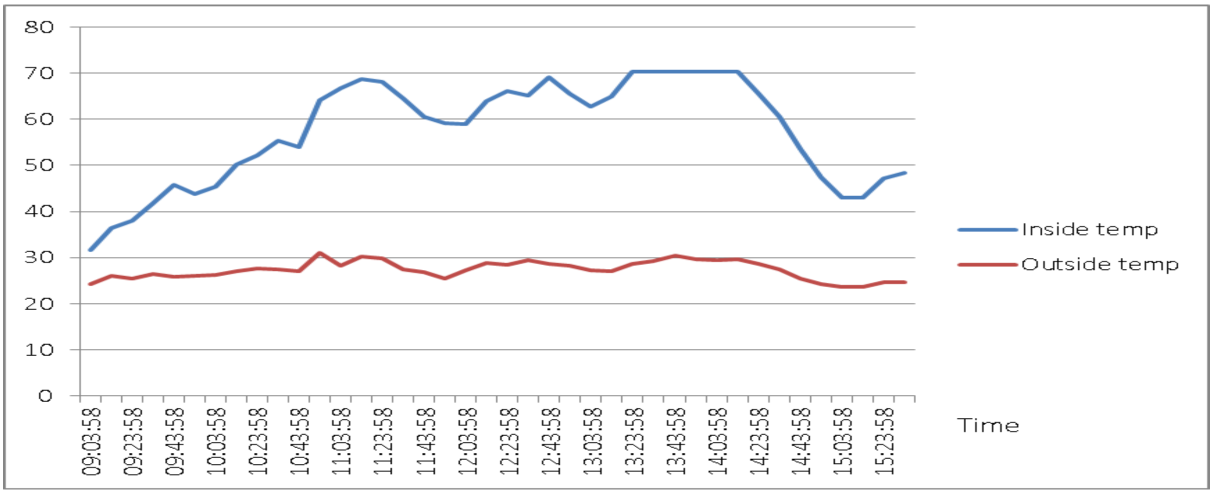

Fig. 2. Internal and ambient temperature (°C) of solar-screened dryer over the drying period of meat and fish

Table 3. Microbial count (cfu/g) of fresh and solar-screened dried beef

Microorganism	Microbial load, cfu/g	
Bacteria	**Fresh beef**	**Solar dried beef**
Coliforms, Proteus spp. and *Micrococcus spp.*	4.5×10^7	No growth
Coliform and *Bacillus subtilis.*	1.0×10^8	No growth
Coliforms, Proteus and *Bacillus subtilis.*	1.0×10^5	No growth
Fungi	**Fresh beef**	**Solar dried beef**
Mucor spp.	2.0×10^6	-
Mucor spp.	7.0×10^6	-
Mucor spp. and *Byssoclamys flavus.*	2.0×10^6	-
Rhizopus spp. and *Cryptococcus neoformans.*	-	3.0×10^4

The drying process of meat and fish took 22 hours to obtain DM content of 88%. The drying efficacy is weather dependent as it is influenced by temperature, sunlight intensity and duration, humidity and wind flow (Fig. 2). Sunlight intensity, relative humidity and wind flow rather than ambient temperature influenced the drying process. During the day, the internal temperature was increased by 28-133% from ambient temperature (Fig 2). The principle of the solar drying technique is to collect solar energy by heating-up the air volume in the meat drying chamber. The high internal temperature could sterilize products however, thermophilic micro-organisms may withstand the heat hence the need for hygienic handling of fresh meat and fish prior to drying.

The results indicated that the level of microbial contamination of fresh beef was higher than the safety level (Table 3). However, the levels in dried products were within the acceptable recommended levels for meat and fish to be considered safe for human consumption. It was only *Rhizopus spp.* and *Cryptococcus neoformans* (Table 3)which were isolated and were considered to be at acceptable levels as recommended by the Ghana Standard Authority

(Table 2). Besides, there was no meat loss and no exposure to vermin. The high levels of microbial loads on the fresh meat were reduced after the drying process, which was evidenced by absence of some micro-organisms or low microbial counts of *Rhizopus spp.* and *Cryptococcus neoformans*. Thus, the solar dryer is capable of sterilising biologically contaminated meat.

Conclusion and Recommendation

The solar screened dryer had drying and sterilising effect on meat/fish and could be used to produce safe products but requires that hygienic procedures must be observed in handling fresh meat and fish before the drying begins to minimize microbial load.

Further study would have to be carried to determine the microbial load of meat and fish dried under the traditional open-air sun drying methods and compare with the improved solar drying method. The solar dryer should also be tried on other meat types besides beef and finally, ascertain the efficacy of the solar dryer on commercial scale.

Acknowledgement

We acknowledge technical support of staff of CSIR-ARI and also from Mr. Jonathan Ampah of CSIR-FRI. Financial support from COTVET for this study is greatly appreciated.

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WESTERN INDUSTRIAL DESIGN OF GHANA'S TRADITIONAL MEDICINE

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Abstract

The past decade has seen a global awakening to the truly curative powers of many ancient medicines. Currently, the herbal products market is a fledging business with the Government of Ghana policy on traditional medicine development providing the impetus for an open domestic market. The policy focuses on areas, which included research and product development, standardization, quality assurance and large scale (sustainable) production as well as technology transfer and commercialization of best products and practices. However, developing wild medicine in the form of leaves, flowers, stem barks, root barks, fruits and seeds into western-style formats remain the key step to transforming the fledging botanicals industry in Ghana.

In a survey conducted by administering questionnaires to over twenty (20) herbal manufacturing companies in the Greater Accra Region, the key cost centers identified in the production set-up were energy (25%), herbs and solvents (35%), waste disposal (20%) and drudgery (20%) whilst preservation and packaging were the key apprehensions that manufacturers have with the development of their products. The High Rate Low Temperature (HRLT) technology of extracting phyto-constituents from botanical tissues (leaves, stem bark, roots bark, fruits, flowers etc) was used to formulate herbal medicines with known concentrations of active ingredients. The herbal medicines are thus presented in both liquid and powdered formats with increased shelf life and efficacy. Hence, the optimized production process and reduced cost of production offer herbal businesses the unique opportunity of applying science and technology to increase profit margins.

Introduction

The past decade has seen a global awakening to the truly curative powers of many ancient medicines. Over 60 percent of traditional medicinal herbs have been scientifically shown to have constituents with therapeutic properties (Melton, 2007). The pharmaceutical industry regularly raids the traditional medicine treasure trove for new therapeutics for different types of diseases. Ghana's flora abounds with plant species with active ingredients that have been exploited in many preparations for their nutritional, fragrance and flavours as well as therapeutic properties (Ghana Herbal Pharmacopoeia, 2007). Currently, the herbal products market is a fledging business with the Government of Ghana policy on traditional medicine development providing the impetus for an open domestic market and efforts at value-addition. The policy focuses on areas, which include research and product development, standardization, quality assurance and large-scale production as well as technology transfer and commercialization of best products and practices (Ministry of Health, 2005). However, taming wild medicine in the form of leaves, flowers, stem barks, root barks, fruits and seeds into western-style formats remain the key step to transforming the fledging botanicals industry in Ghana. Out of about 147 small-to-medium scale herbal industries, only 15 use industrial grade equipment consisting mostly of hot air tray driers, stainless steel boiling vessels, automatic mixing vessels and bottling lines, manual or semi-automated capsule filling with powdered plant parts (Essegbey *et al*., 2014). The harnessing of the emence economic potential of this treasure trove through the application of science and technology is the focus of contemporary research in Ghana (Oduro & Addo-Yobo, 2015) (Oduro & Addo-Yobo, 2013).

Presently, however, most practitioners in herbal production use very laborious rudimentary processes in the extraction, preparation and packaging, which eventually lead to a loss of quantity and quality of the products as well as a reduced shelf life. Typically, plant materials are soaked or boiled in water or ethanol using open vessels and the liquid final products so obtained, in very dilute forms, poses an added challenge with storage as the final products have high moisture content, which makes it amenable to degradation in a short time (FAO Corporate Document Repository, 2015). Another challenge is with the high cost of production, as large volumes of solvents need to be boiled at a relative high temperature with no solvent recovery systems leading to huge losses. The high, uncontrolled, processing temperatures can also lead to deactivation of the phyto-constituents rendering the products less efficacious. In addition, the in-exhaustive extraction process, in cases of cold maceration (soaking tissues in the extraction liquid at room temperature to soften them after drying to a low moisture content of about 6-10%) leads to waste as significant quantities of active ingredients are still locked up in the plant tissue (or marc). A review of the sector conducted about three decades ago identified the need to introduce screw-press filters to extract the juice from the marc and methods for drying extracts, into their manufacturing operations (DANIDA/MOH, 1985). However, these innovations have still not been introduced into manufacturing. By conventional practice, plant materials with non-polar phyto-constituents as active principles are marketed in the form of pulverized plant tissue packed in capsules without prior extraction, which leaves the plant fibre as active sites for the growth of microorganisms.

The objective of this paper is to highlight the main drawbacks to the manufacturing processes of fifteen (15) herbal companies in the Greater Accra Region of Ghana and proffer technological solutions for the development of their processes that will enhance the value (qualitative and quantitative) of herbal products. It also demonstrates the capability of CSIR-IIR in using the High Rate Low Temperature extraction process to improve packaging for a typical herbal manufacturing company in order to increase marketability of their products on both the local and international market.

Methodology

Baseline survey

A structured questionnaire was administered to fifteen (15) herbal manufacturing companies with businesses spanning herbal medicine producers, exporters of plant tissues, distillery companies, and manufacturers who use herbal products in their production line. The respondents were top management personnel (Chief Executive Officers, Presidents, and Managing Directors) as well as middle level managerial staff (Production managers, Engineers and Technicians). A workshop involving thirty eight (38) participants from both public (research, academia as well as policy and regulatory institutions) and private stakeholder institutions in the herbal medicine and botanical extract products industry in the Greater Accra region of Ghana was organized to validate the results from the questionnaire. The workshop adopted an inclusive and participatory approach to discuss the veracity of the outcome from the analysis of the questionnaire.

Innovation to the Process development

Material preparation

The raw materials delivered by clients in the form of plant fruit, leaves, seeds, stem and root barks and flowers are air dried and milled to increase the surface area, which facilitates exhaustive extraction. The appropriate solvent system and the ratio of plant material to solvent were selected by pre-extraction assessment based on the chemical composition of the active ingredients in the plant tissue. The plant material and solvent system was fed into the extractor rig and exhaustively extracted by bringing the mixture to boil at low temperatures (50 ^{o}C) under vacuum for about two (2) hours. The liquor (liquid extract) was removed into a concentrator through an on-line filtration system to be concentrated into syrupy liquor by distilling off the excess solvent. The solvents were recovered in the concentration step and stored to be re-used for subsequent extractions. Qualitative and quantitative analysis using a combination of wet chemical analysis and spectroscopic analysis was conducted on the syrup to determine the concentration of active ingredients before crystallization and drying into a powdered form using an incipient wet impregnation technique on an inert base in a crystallizing tank. A quality assurance check was conducted by analyzing the final product to proof check the concentrations of the formulation before delivering to client for packaging and marketing. Figure 1 gives an outline of a typical process and Figure 2 gives a schematic representation of the process on the high rate low temperature botanical extraction rig.

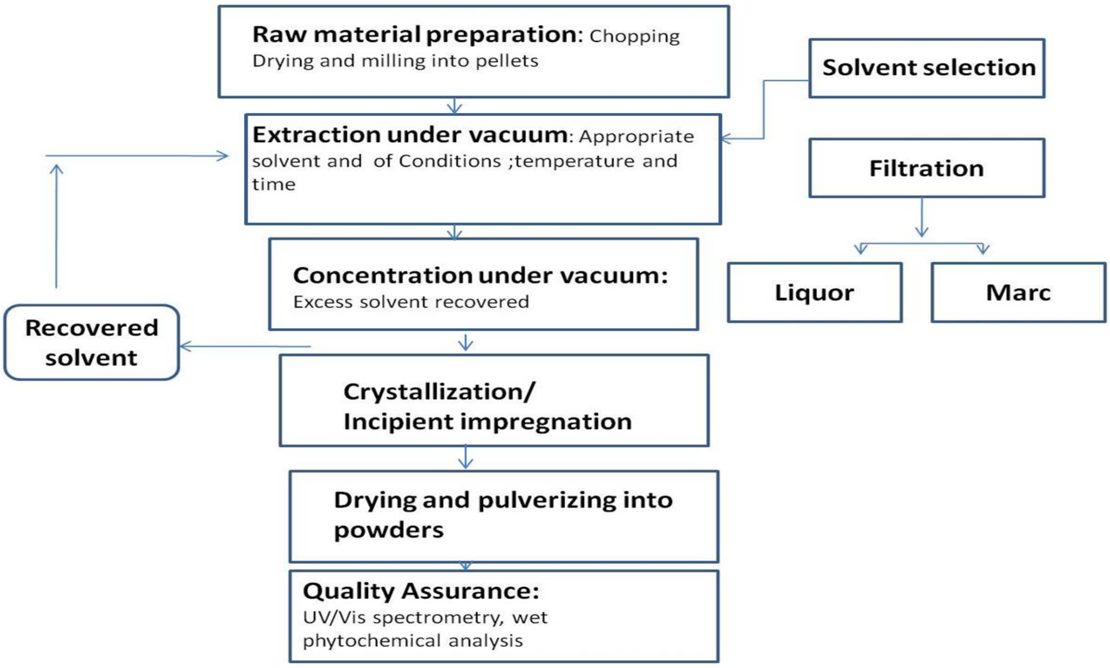

Fig. 1 A flowchart of the process flow in value addition of medicinal plants

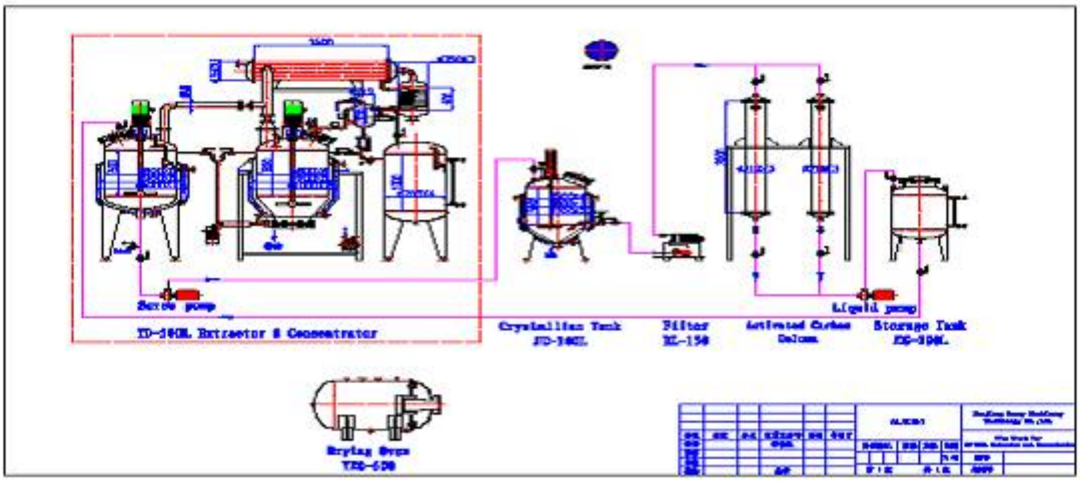
Fig.2 A schematic diagram of the process in a high rate low temperature botanical extraction plant.

Private sector partnership

Since the herbal industry in Ghana is mainly private sector led and driven, a necessary imperative for the sustainable adaptation of an innovative step must include partnership with the private sector to realize the goals. Tinatett Herbal Manufacturing Company Ltd is one of the leading herbal medicine producers in the country with a staff strength of thirty five (35) of which twenty three (23) are females and an annual turnover of about six hundred thousand Ghana Cedis (GH¢ 600,000). About twenty-two (22) different products are marketed both on the local and on the international market under the Trademark Tinatett Herbal. Tinatett was strategically chosen in this study because of the market size they control and because they showed strong inclination to using technology to become a market leader in the herbal industry. Their products are in the form of liquid extracts and pulverised plant tissue. Through a memorandum of understanding, Tinatett Herbal provides all the raw material input and a commensurate cost of the services provided by the CSIR-IIR High Rate Low temperature Extraction pilot plant in return for purified dried extract, concentrated syrups or pure phyto-chemical crystals/fine powder.

Results and Discussions

Structure of the herbal industry in Greater Accra Region

The herbal industry in the Greater Accra region are generally small to medium scale enterprises employing on the average a minimum of 15 persons, however, there are a few big companies in the distillery industry. Each trademark usually consist between fifteen (15) and fifty (50) different product lines which come in the form of liquid extracts or milled dry plant tissue. The extraction is mainly done by cold maceration or boiling with water as the main solvent or in few cases local gin (30-35 vol. % ethanol) for extraction times that average between two (2) to twelve (12) hours using varying forms of heat energy from liquefied petroleum gas (LPG), biomass or electricity sources. The herbal industry in Ghana feeds both local and international market.

Contribution of key cost centres in the production cycle of typical herbal manufacturers in Greater Accra region of Ghana

The key cost centre in the production cycle which was of major concern to the industry is the cost of energy (25%) mainly from LPG or biomass sources with electricity used in milling the plant tissue into the powdered form. The cost of raw materials (22%) is also a source of concern as with the drudgery of the operation (20%) and waste disposal issues (20%). Solvent for the extraction was of least concern to the participants since they use mainly water and in few cases 30-35 vol. % of ethanol for the extraction. The contribution of each of the five (5) major cost centres to production is illustrated in Fig. 3.

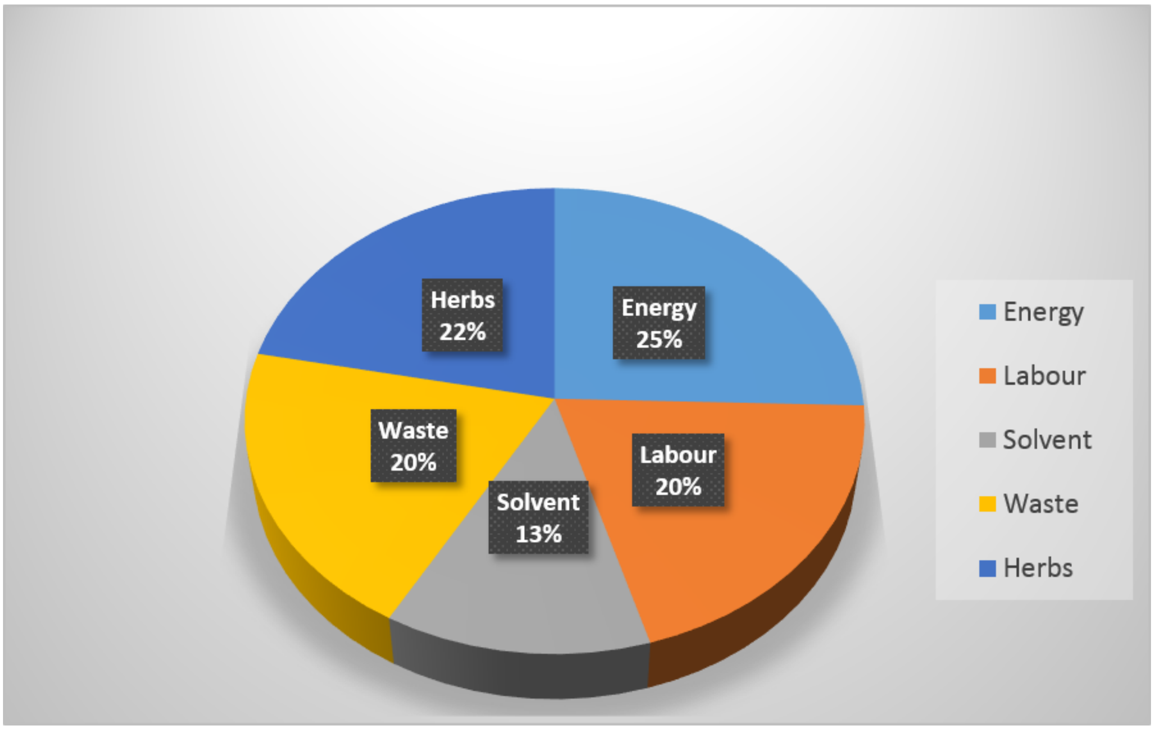

Fig. 3 Level of concern of production cost centres

Thus, it is envisaged that the HRLT botanical extraction pilot plant could help in driving the cost of raw materials as a factor in the cost of production further down by optimizing the extracted yield. In other words, the quantity of raw materials used to produce a batch could be reduced significantly through efficient extraction practice. Similarly, the fully automated semi-continuous process of the HRLT technology would reduce drudgery with the almost closed solvent recovery system ensuring minimal cost with solvents. Heating under vacuum affords solvents to reach boiling point at relatively low temperatures as the vapour pressure of the system rapidly reaches optimum at considerably reduced extractor's ambient pressure. Hence, the turbulence of boiling which ensures good agitation is achieved at lower temperatures thus not compromising the thermo-labile constituents of the extract. The advantage of outsourcing the extraction process of the production line is in the transfer of the waste management issues to the service provider (CSIR-IIR). The service provider also has the benefit of tonnage to put the spent waste into sustainable reuse options, thus ensuring cleaner and sustainable production.

Levels of apprehension in the various processing steps in the production line

In determining the issues in the production cycle of the herbal manufacturing sector of priority concern to the participants, preservation ranked highest (31%) followed by packaging (22%) whilst purification of products was of least importance to them (8%). Materials preparation and extraction together constituted about 39% of the priority concerns in the production of the respondents (Fig. 4).

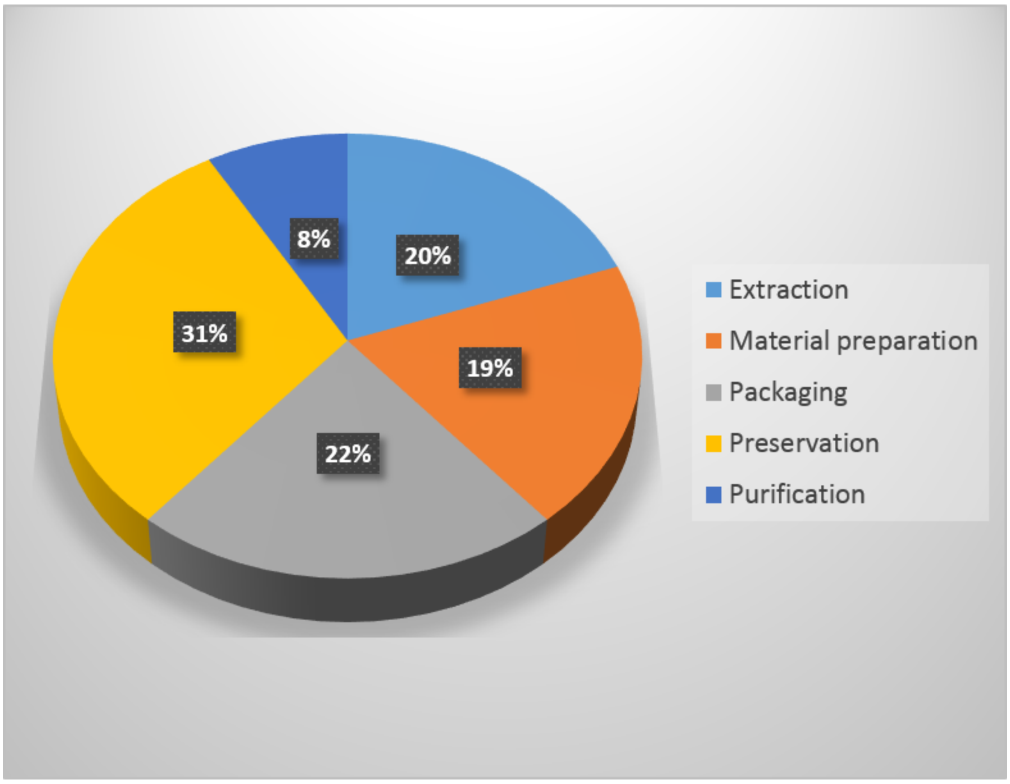

Fig. 4 Production needs as prioritized by participants at the workshop

The weight of concern of the various processing steps was expected, given the process methods used by most of the participants, which involved extraction with water, or milling of the plant tissue into coarse powder form. Thus, the products have high moisture content, which provide active conditions for fungal and bacteria growth as well as initiating chemical reactions leading to reduced shelf-life or product failing the limit to microbial load test of the FDA. The need for preservation of the final product as liquid extract or presentation of dried extracts or pure phytochemical crystals / powders, then becomes necessary to guarantee longer shelf life. Water activity is a measure of the free water in the product. It is well known that each microorganism has a critical water activity (a_w) below which growth cannot occur. Pathogenic microorganisms cannot grow at $a_w < 0.86$, moulds are inactive at $a_w < 0.62$. At a_w 0.30 the product is most stable with respect to lipid oxidation, non-enzymatic browning, enzymatic activity and hydrolysis reactions (FAO Corporate Document Repository, 2015). Though the relationship between water content and water activity is complex, an increase in water content is usually accompanied by an increase in water activity but in a non-linear fashion. Though the participants said they were satisfied with the shelf-life of their products since FDA-Ghana currently give only a limit of one year shelf-life to all herbal medicines they were upbeat about interventions aimed at adding value to their products as well as extending the shelf- life of the product. It is of interest also that improving the material preparation and the extraction processes can significantly affect the preservation of the product by lowering water content through vacuum distillation in the concentration crystallization and drying step. The participants however, were not keen on isolating active compounds and marketing their products in western style formats like the artesunate, 5-hydroxytryptophan etc perhaps because there is not a single active ingredient responsible for the pharmacological properties of the herbal product but a holistic combination of synergistic and inhibitory biologic responses contribution from various phyto-constituents from same or different plants.

Process development for a herbal manufacturing company

Per their present production practice, Tinatett Herbal produces 2000 L of products per batch of 300 kg plant material. Using the HRLT technology concentrates of phytochemicals extracted from plant tissues was produced to be diluted and repackaged for the market. A similar batch of 300 kg of plant tissue was extracted and delivered to the company in the form of syrup concentrates about ten (10) times more concentrated than the standard Tinatett batch as indicated in the UV-Vis spectrum in Fig.5. 2,560 L of the product was obtained from the same batch quantity of plant material (300 kg) indicating about 1.3 times increase in yield. This translates into more products from the same raw material demonstrating savings in the cost of raw materials in the production process by nearly a third. The drudgery of the present production process, which involved manual production steps, was reduced by the introduction of the automated systems at the HRLT extraction. In addition, the problem with management of the waste plant material at the Manufacturer's premises was eradicated as the only process remaining to be done at the manufacturer's factory was dilution and bottling.

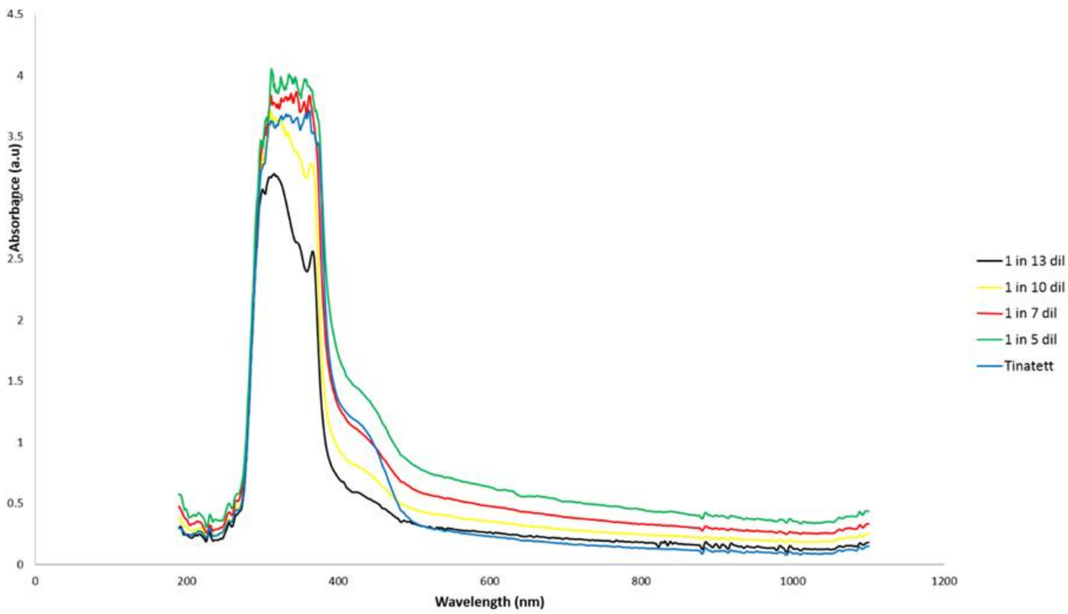

Fig 5: A UV-Vis spectrum of a typical batch sample of liquid medicine from Tinatett and serial dilutions of the concentrate from the HRLT extraction. The yellow spectrum showing a 10 times dilution of the

concentrated syrup from the HRLT extraction matching very well with the blue spectrum from a typical Tinatett batch.

To demonstrate the potential in westernizing indigenous herbal medicine often administered in the form of raw barks or pulverized plant tissues in capsules by Tinatett Herbal, 200 kg root bark of a plant material has been extracted with 1400L of solvent 50% vol/vol aqueous ethanol and concentrated to 68L syrup with concentration 224.38 g/L. The yield (active ingredients per kg of raw material was 4-6% wt./wt.) The concentrate tested positive for, reducing sugars, alkaloids, sterols/cardiac glycosides, tannins, saponnins and flavonoids as in the original raw plant tissue. The powdered formulation with known concentrations of extract in purified dry starch (as disintegrant and diluent) has been prepared and capsulated (as shown in Fig. 6) with excellent efficacy during the pharmacological and clinical trials, improved shelf life, and market appeal.

Fig. 6 Plant medicine from Tinatett Herbal formulated and packaged into western-styled formats; a) Raw root bark, b) powdered formulation, c) capsulated product and d) Packaged product for market.

Conclusion with Policy Recommendations

The efficacy of herbal medicine in the treatment of certain medical disorders is a well-established fact. This paper demonstrated that it is possible to improve the quality and efficacy of herbal preparations through the High Rate Low Temperature botanical extraction technology and establish right concentrations for managing dosage using spectrophotometric analysis of phyto-chemicals constituents at each stage. The yield of phyto-constituents extracted from plant tissues and recovery of solvent could be remarkably enhanced by between 20-80% through exhaustive extraction procedure and the powdered herbal formulations have extended shelf life and increased market penetrability.

There is however, a need for a policy intervention that will seek to bridge the gap between research and technology transfer and the many small to medium scale enterprises that dominate the herbal industry. Such an intervention that addresses the information and technology gap could include the setting up of large-scale production facilities to be placed at the disposal of the small and medium scale enterprises, who might not afford having a facility on their own, for contract processing at a subsidized fee to transform knowledge and technology into well-researched products and processes. This will help formalize the sector and secure the indigenous knowledge into more profitable business opportunities for shared growth.

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MECHANIZED PALM KERNEL SHELL SEPARATOR FOR SMALL SCALE KERNEL OIL CHAIN

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Abstract
A mechanized palm kernel- shell separator has been designed, fabricated and field tested by the Institute of Industrial Research of CSIR. When compared with the clay bath separation method being undertaken by small-scale palm kernel oil producers, this separator has eliminated the use of water and clay in the kernel shell separation process thereby improving the hygiene of the process and ultimately increasing labor productivity of the small-scale palm kernel shell separation process. This design combines two distinct separation techniques into a single compact unit made up of a two-ply rotary screen and an inclined belt conveyor**.** Palm nut cracked mixture is fed through a hopper and separate outlets are provided for kernels; shells and fine debris. At a capacity of 500 kg/hr, the efficiency of separation ranges between 80% and 90% depending on the cracking efficiency of the nuts.

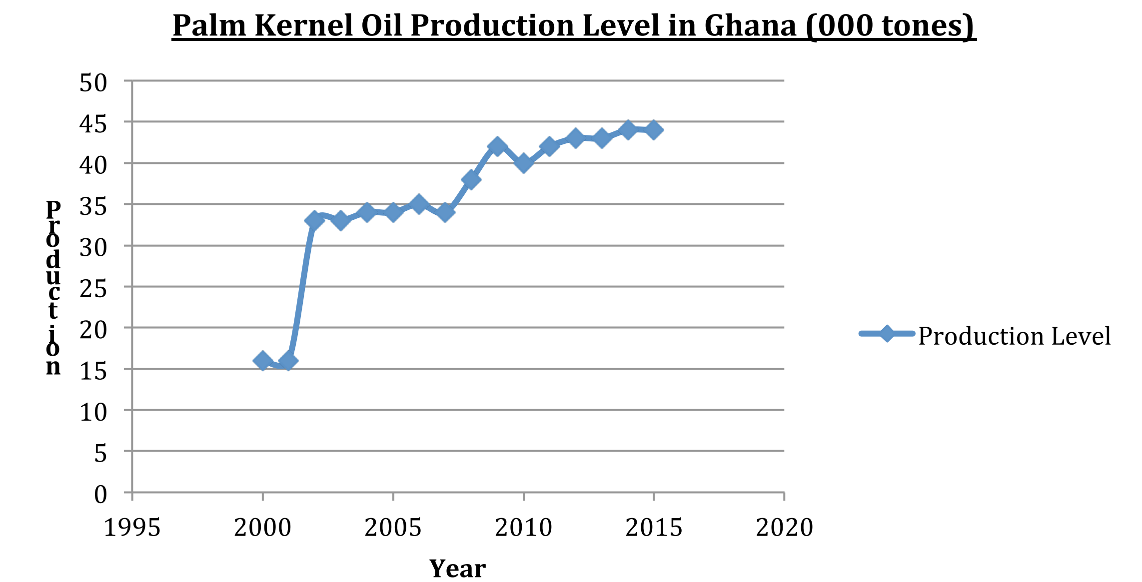
1.0 Introduction
Palm kernel oil production is one of the very distinct activities undertaken by mostly poor rural women living in seven out of the ten regions of Ghana where oil palm plantations and farms are established. Over the years a number of interventions by way of the introduction of mechanized equipment have been made to reduce the drudgery associated with palm kernel oil production and also increase productivity. The mechanized palm kernel shell separator is an innovation that seeks to provide a solution to the rather elusive challenge of separating kernels from shells on a small scale mechanically without the use of clay and water, which has been identified as problematic.

1.1 Background
The wanton destruction of several hectares of cocoa farms in Ghana due to the disastrous drought and bush fires of 1983, caused many farmers to opt for oil palm as a substitute cash crop instead of cocoa. The introduction of the Presidents Special Initiative on Oil Palm which added over 20,000 ha of small scale farms further boosted the cultivation of oil palm in Ghana. About 305, 785 ha of land is covered by oil palm according to the most recent survey records published by Ghana's Ministry of Food and Agriculture. Today, the total oil palm fruit production has increased from less than 800,000 tonnes fresh fruit bunches (FFB) in 1983 to well over 4 Million tonnes in 2014. According to a Ministry of Food and Agriculture's brief on the oil palm sector

in Ghana, it is estimated that 243,852 tonnes of palm oil is being produced currently. A major by-product of palm oil production is the palm nut; which contains an oil-bearing kernel. Given kernel extraction rates for the West African sub-region as 5.1% FFB; a potential of more than 204, 000 tonnes of palm kernel per annum is currently produced in Ghana.

It is estimated that about 56% of palm nuts are produced by small-scale processors, 32% by large scale mills, 9.8% by traditional processors, 2% by medium scale mills and less than 0.2% from restaurants, chop bars, and household palm soup sources.

At least two levels of technology could be described for palm kernel processing in Ghana. These include the large and medium scale expeller mills and the indigenous traditional extraction techniques. The major palm kernel oil (pko) producing mills in Ghana are Ayiem Oil Mills, Juabeng Oil Mills, Tringo Oil Mills, Golden Webb Limited and Ghana Oil Palm Development Corporation Mills, Twifo Oil Palm Plantation Limited, Benso Oil Palm Plantation Limited, and NORPALM Ghana Limited. From a production level of 16,000 tonnes in 2000, palm kernel oil production in Ghana has risen to 43,000 tonnes in 2015 according to the United States Department of Agriculture as shown in figure 1.



Source: United States Department of Agriculture; September 2016

Figure 1: Palm kernel oil production levels in Ghana

It is estimated that small-scale indigenous women processors, using traditional techniques process between 40 and 70% of available palm nuts in Ghana into palm kernel oil annually. These women who are spread over seven out of the ten administrative regions in Ghana, employ very crude methods that are mostly laborious and time consuming, and yet account for over 70% of palm kernel oil production in Ghana.

The traditional process of palm kernel oil extraction from dried and cleaned nuts consist of a chain of seven operations: cracking the nuts, separating kernels from shells, drying kernels, roasting the kernels, milling the roasted kernels, boiling and skimming the milled paste to collect oil.

With the advent of palm nut crackers, the nuts are cracked mechanically using these crackers thereby almost totally eliminating the problem of cracking as a bottleneck Aggey, M. et al. (2007). The conventional clay bath technique is then employed to separate palm nut cracked mixture into the kernels from the shells. This involves the use of clay mixed with water to obtain clay bath slurry, which is mixed thoroughly with the material to be separated. Differences in specific gravity of the various constituents of the mixture aid in the separation of the kernels from the shells. Kernels with a specific gravity of about 1.02 float on the surface of the clay suspension whose specific gravity should be about 1.12. The shells, which are the heaviest of the three main constituents, have a specific gravity of about 1.2, and therefore sink to the bottom. Hand picking, manual winnowing and the use of a brine solution are other methods of trying to separate the kernels from the shells with varying but unsatisfactory levels of success.

Sun drying of the kernels is carried out to reduce the moisture content of the kernels prior to roasting. The dried kernels are manually roasted in roasting pans, and milled through the use of attrition mills, after which the oil is extracted by boiling and skimming.

1.2 The Problem

A study of women palm kernel oil producers in Maamobi, a suburb of Accra, ranked winnowing of cracked nuts and using the clay-bath to separate kernels from shells, respectively, as first and second most difficult and disliked activities among all the processing operations (Aggey, M.1990). Thus in spite of immense potential availability of palm kernels, facilities to convert the palm nuts to kernels are limited. Actual palm kernel production is between 23% and 28% of the potential. Separating kernels from shells after cracking the nuts is a major bottleneck for small scale producers and over 70% palm kernel oil producers are small scale and use the clay bath method.

1.3 Objectives

The specific objectives of the project were to eliminate the use of water in the kernel shell separation process; eliminate the use of clay in the kernel shell separation process; increase labour productivity of palm kernel shell separation. Introducing the mechanized kernel shell separation system would increase the market share and income level of women oil-makers and owners of nut-cracking and kernel separation facilities.

1.4 Justification

Palm kernel oil has many useful applications both locally and internationally as edible oil, and by hydrogenation to make margarine and cooking fats. It is also used in the production of glycerin, cosmetics, soap, detergents, and industrial chemicals for textile processing as well as for medicines. By-products of palm kernel oil can be used as substitute for cocoa butter, as well as palm kernel cake, animal feed, candle and a variety of industrial uses. It is obvious that the palm kernel oil is a recognized product on both the local and world markets for its usefulness. Palm kernel shells which are a major by-product of the palm kernel oil production process are the fractions left after the kernels have been removed from the cracked kernel shell mixture. The Moisture content of shells varies between 11% and 13% which is relatively low when compared to other biomass residues. Shells are a good quality biomass fuel with uniform size distribution, easy to handle and generates limited biological activity due to its low moisture content.

Almost all the palm oil mills in Ghana are self-sufficient in terms of energy by making use of kernel shells and mesocarp fibers in cogeneration. The demand for palm kernel shells has increased considerably in the oil palm production countries such as Malaysia, Indonesia and Thailand resulting in prices inching close to that of coal. It is also reported that some cement industries are using palm kernel shells to replace coal. Thus an increased output of the palm kernel oil industry will deepen agro-processing expanding the national export base with concomitant employment generation, increasing income and contributing immensely to national development.

Key factors constraining increased palm kernel oil production in Ghana include limited industrial production facilities to convert palm nuts to kernels for processing into oil and inefficient traditional processing techniques. It has been estimated that only between 25 - 27% of Ghana's potential palm kernel production is done in large/medium scale industrial processing because installed palm nut cracking and processing facilities are few. As a result, traditional processing techniques employed by a large number of women oil-makers, spread throughout 7 of the 10 regions of Ghana, account for 40 - 70% of palm kernel processing in Ghana.

Unfortunately, traditional and indigenous oil processing techniques have been generally reported as wasteful and unprofitable. Key among the operations requiring modification and upgrading are the winnowing and separation of the kernels from the shells after cracking the nuts. A kernel shell separation system to combine both the winnowing and separation activities at a go thereby saving the processor over 28 man-hours per ton of processed kernels was considered a step in the right direction.

1.5 Existing technologies

Two methods of separating kernels from shells after cracking are being employed all over the world. These are the wet methods and the dry methods.

Wet methods

These include the use of clay bath or kaolin, salt solution and use of hydro cyclones for medium to large scale processors. Wet methods have the major disadvantage of requiring further washing with clean water and drying in cases where clay or other chemicals are used and drying the washed material before further processing

Dry methods

Dry methods include the traditional hand picking (manual), the use of screens/trommels (semi mechanized) and aero cyclones (fully mechanized) for medium to large scale processors. Dry methods have the added advantage of not requiring any further washing prior to processing but in the exception of hand picking usually require some form of mechanized or semi mechanized equipment.

Palm kernel shell separation in Ghana in most large scale mills is by a combination of pneumatic systems and hydro-cyclones to clean and separate kernels from the cracked mixture. Some mills use huge mechanized clay-bath systems in place of the hydro-cyclones replacing the clay with kaolin in the bath. All the women at the "krammer" mills use the clay-bath for kernel separation. Krammer mills are local small scale mills spread all over the oil palm production areas of Ghana where palm fruits are processed by women processors to produce palm oil and palm kernel oil. Krammer is the name of a Belgian engineer who first set up a small-scale mill in the Kwaebibrim District in the Eastern region of Ghana in 1982.All the women operating at these mills affirm that the clay-bath method of separation takes a heavy toll on them. Whilst the women processors expressed willingness to pay for kernel separation services if available, "krammer" proprietors on the other hand indicated a desire to acquire a kernel separator if manufactured.

A rotary sieve, manually operated or motorized is extensively used in the field as a winnowing device prior to clay-bath separation. In some cases, the rotary sieve is supplemented with a small motorized blowing unit for winnowing out debris. This equipment is a cleaning device for removing fibrous debris and smaller pieces of broken shells from the cracked mixture before separation in the clay-bath.

Till date no mechanized palm kernel shell separator with satisfactory performance and efficiency has so far been designed and manufactured locally.

A design of a mechanized palm kernel shell separator that would be acceptable to the beneficiaries, given the current situations must incorporate into the design parameters existing palm nut cracking rates as well as the cleaning rates.

The clay bath technique that is commonly used in the separation of kernels from shells requires the use of high quality clay in large quantities as well as water. The clay suspension should be kept at constant specific gravity by continuously stirring it to prevent settling of the clay particle and also frequently adding more clay to compensate for that which is lost on the shells, kernels and other particles as they settle. For every tonne of cracked mixture, about $7m^3$ of clay is required, leading to environmental degradation at the excavation site. Close to 700 litres of water is used in processing each ton of nuts in the clay bath operation alone; besides the need to wash the kernels after separation (Aggey, 1990). Introducing the mechanized kernel shell separation system would eliminate the use of water, eliminate mandatory drying after rinsing the kernels, raise productivity and reduce environmental degradation in kernel processing. It will also increase the market share and income level of women oil-makers and owners of nut-cracking and kernel separation facilities.

2.0 Materials and Methods

Standard sieve analysis was conducted on palm nut cracked mixture to obtain some of the major physical characteristics of palm nut cracked mixture. Samples were obtained from small-scale palm kernel oil producers and processors in the Kade, Kusi and Takorase areas in the Eastern Region of Ghana. Results from the analysis indicate that palm nut cracked mixture contains 27% kernels, 70% shells and debris and 3% un-cracked nuts. It was further found that 0.5% of kernels have average diameter of less than 5 mm. Most of the kernels (91.5%) have diameter ranging between 5 mm and 10 mm. About 8% of kernels have diameters greater than 10 mm. On the other hand, 97% of the un-cracked nuts found in the cracked mixture have diameters greater than 10 mm. All debris was less than 5 mm in size. These results formed the basis of selection of sieve aperture.

Separation of materials into various size groups using a screen surface required the determination of the maximum dimension of the undersized material and the screen aperture. The number of times the material to be screened must impinge on the screen surface to achieve the desired separation vis-à-vis the dimensions and rotational speed of the rotary sieve were parameters that were established as part of the design process. According to Alter et al. (1980), the rotational motion of a barrel and its inclination relative to the horizontal provide the means by which material fed to the rotary sieve is made to impinge on the screen surface. The number of impingements a mass of particles experiences during its residence in the rotary sieve is a function of its dimensions, its rotational speed and angle of inclination. These considerations employed during the primary basis for the design.

Friction characteristics of various components of the cracked mixture on three surfaces nylon, tarpaulin rubber, and jute were undertaken and simulated with various speeds of the belt at various inclinations to determined belt speeds and angles for the three materials. Engineering based computations were done to determine various component sizes and other parameters.

Other considerations include the need for the equipment to be affordable for women groups or individuals involved in small scale palm kernel oil production with price ranges of GHC8,000 (US$2000) to GHC12000 (US$3000) and with the possibility of being paid for over a period of not more than three years.

For easy transfer and adoption it was also necessary for the equipment to easily fit into the operations of existing Krammas in the Kusi, Kade and Takorase areas of the Eastern region of Ghana where it could also be operated as a Service Facility
Most of the processors are women and so the equipment operation and performance must suit women who would be the main beneficiaries
A design concept that combined separation using a sieve and a conveyor belt considering the shape and frictional properties of the constituents was formulated.

2.1 Design considerations

2.1.1 Rotary Sieve

The main parameters sought after in the design of the sieve included screen aperture, rotary sieve speed, rotary sieve diameter, rotary sieve length, and rotary sieve capacity.

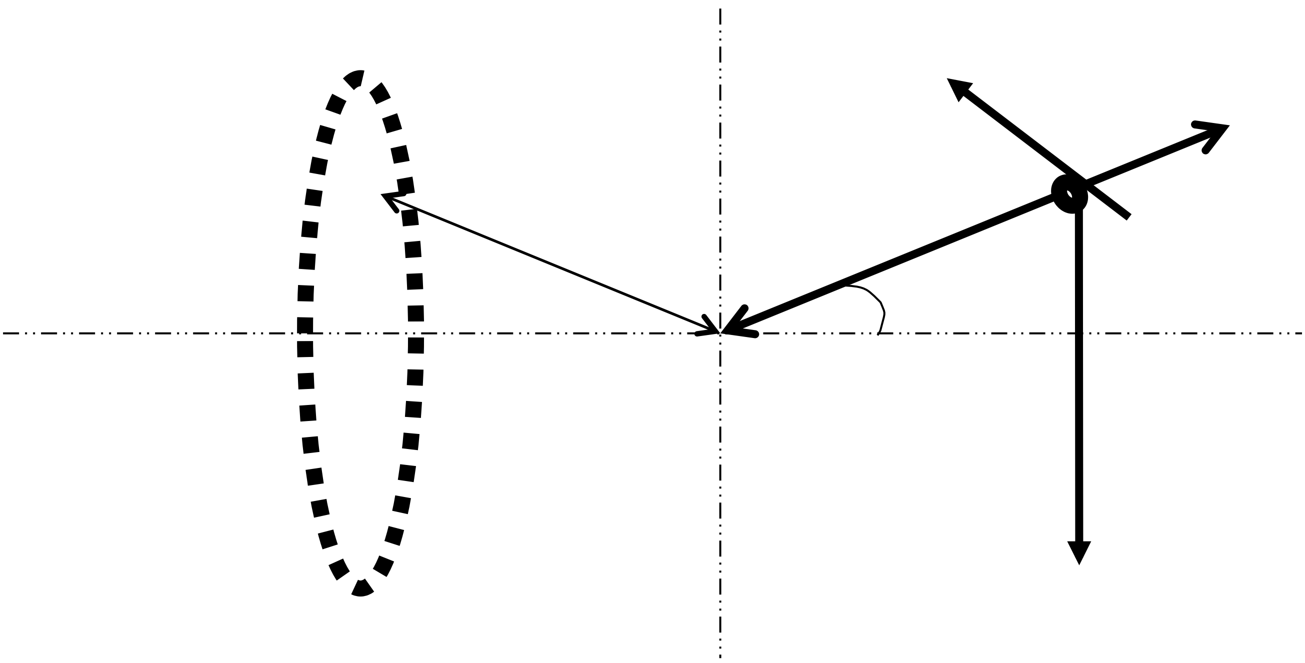


Figure 2: Schematic Diagram of Rotary Sieve

Sieve Speed
Referring to figure 2, an acceptable speed of the sieve may be computed from the equation

$$\omega = \left(g/_{R \sin \theta} \right)^{1/2}$$

Where ω is the angular speed, R is the radius of the rotary sieve and □ is the angle of repose for kernels, g is acceleration due to gravity.

To achieve the screening function, the material to be screened must necessarily slide over the internal surface of the perforated sieve and carried up with influences from gravity, centrifugal force and friction such that at an angle θ, (Fig. 2) the material begins to cascade down the side to the bottom of the screen. The maximum angle of lifting of the material is approximated to be the angle of friction. However, $= \mu$; Where μ is the coefficient of friction of the materials on the galvanized steel surface used for the sieves.

Ezeoha et al. (2012) reports that the coefficient of friction for kernels on galvanized steel for dura and tenera are 0.48±0.1 and 0.56±0.15 respectively. Though the material is a mixture of dura and tenera kernels, it is predominantly tenera and considering the coefficient of tenera kernels to be 0.56±0.15 a coefficient of 0.61 was selected.

Thus θ = 31.4° and N = 75.5 rpm

At 50%, the speed would be 37.75 rpm.
Based on this, a design drum speed of 40 rpm was chosen. With this speed, the diameter, length, and capacity were computed.

The two galvanized iron wire mesh screen have screen openings of 5mm and 10mm and taper of 10°. This taper angle was selected on the basis of computations involving the time required for the material to move from the feeding end to the discharge end as well as the speed of the cylinder

Also, a Critical Speed above which the constituents of the mixture will get stuck to the screen surface could also be obtained from the relationship

$$N_c = {}^{1}/_{2\pi}\sqrt{{}^{2g}/_{D}}$$

Where N_c is the critical speed and D is diameter of sieve

Diameter

The diameter of the rotary Sieve depends on the total capacity of screening. This notwithstanding, the drum should according to Sullivan J. W. et al (1992) be sized to be between 25% and 33% full of material to be screened. Incorporating the bulk density of the material and slope of the drum, the diameter of the rotary Sieve was computed from the equation

$$D = \left(\frac{11.36Q_m}{d_b\, FKtan\alpha\sqrt{g}}\right)^{0.4}$$

Where:
D is diameter of sieve
d_b is the bulk density

F is the fill fraction
K is Velocity correction factor
Qm Mass throughput
□ is slope of sieve

Length
The Sieve Length similarly was computed from the equation

$$L = 0.113TKtan\alpha\sqrt{Dg}$$

where
L is the length of the sieve
T is the residence time
K is the velocity correction factor
D is the diameter of the sieve
□ is the sieve slope
g is acceleration due to gravity

Capacity
A review conducted by Sucher and Pfost (1964) indicated that the capacity of cylindrical sieves increased with increased speed up to a point where blinding occurs due to the crowding through the screen. Increasing the rotational speed to its critical value resulted in material being carried around the cylinder without cascading over its surface. The cleaning device was designed with small to medium scale palm kernel oil processors as the target beneficiaries. Amoah, J. Y et al (2007), reports that the minimum, maximum and average cracked mixture sieving throughput rates are 298.6 kg/hr, 1932.1 kg/hr and 932.2 kg/hr, respectively. Since over 70% of the processors are small scale, a throughput rate of 500 kg/hr (0.15 kg/sec) was selected as the design capacity. Using this as a basis, the other key parameters were computed through the application of appropriate design equations discussed.

To compute the capacity of the sieve the equation

$$Q_m = d_b Q_v$$

and

$$Q_v = 0.088FKD^{2.5}g^{0.5}tan\alpha$$

Where
D is diameter of sieve
d_b is the bulk density
F is the fill fraction
K is Velocity correction factor
Q_m Mass throughput
□ is slope of sieve

Velocity correction factor K_v
Kamil E. E. (1981) developed an equation for a kinematic factor of motion, which considered all the forces that are brought to bear on the motion of the

particles in a rotary sieve. According to Kamil E. E. (1981), $K_v = \left(\frac{\mu^2+1}{\mu^2}\right)^{1/2}$ where μ is the coefficient of friction.

Fill Fraction
Palm nut cracked mixture contains a lot of debris with a potential to blind the sieve holes if the feeding rate of the material is high. For effective separation, a very low fill fraction of 5% was selected for the design.

Bulk Density
Bulk density of the palm nuts cracked mixture was determined based on procedure recommended by ASABE (2003): A container with a volume of 0.5 liter was filled with palm nuts cracked mixture and leveled at top surface without compacting the contents of the container and weighed. Bulk density of the cracked mixture was obtained as the ratios of the mass of samples in the container to the volume of the container. The equation employed based on the standard procedure described is $\mathrm{d}_b = \frac{M_m}{V_m}$ where, V_m is the sample volume of cracked mixture and M_m is the mass of cracked mixture. This was found to be 511.14 kg/m^3

Shape and Slope
Rotary sieves are normally cylindrical in shape and inclined at an angle. To take advantage of greater screening surface area for the same length of the sieve a two-ply truncated conical sieve was considered. The minor diameter of the truncated cone corresponds to what would have been the diameter of a rotary sieve and half the cone angle corresponds to the angle of inclination. Computations show that using a truncated cone instead of a cylindrical and inclined drum reduces the length of the drum by as much as 40% for the same lateral screening surface area and throughput. A two-ply sieve was considered to allow for size categorization of the cracked mixture into two streams thereby further increasing efficiency of separation on the two screening surface for each category of material.

Research shows that the efficiency of screening decreases with increasing angle of inclination of the sieve and empirical data suggests that angles of not more than 15 degrees are most likely to produce best results. For a given set of operating conditions, decreasing the inclination angle will increase the residence time, which in turn results in an increase in the screening efficiency and concomitantly will increase the bed depth which in turn results in a decrease in the screening efficiency. On the basis of these relationships, and some empirical data, 20 degrees was chosen as the cone angle for which half the cone angle was 10 degrees.

Rotary sieves are slopped in order to facilitate the flow of material as separation takes place. With a conical sieve mounted on a horizontal shaft, the taper angle is assumed to be the slope of a normal cylindrical sieve. The slope also affects the length, diameter as well as efficiency of separation. It is more likely that a particle will pass through a screen hole if the slope is small thereby increasing the efficiency of separation. The slope also affects the travel rate and the time it takes the material to stay on the screening surface (residence time). Meanwhile, the travel rate also depends on speed of the drum and its diameter. According to Klemin et al. (1985), the slope of a cylindrical sieve on the horizontal plane (sieve inclination angle) should be less than 27° and also less than the friction angle between the material and the sieve surface. An inclination angle of between 10 and 15 was considered as best for maximum separation efficiency

2.2 Inclined Conveyor

A conveyor is essentially an endless belt operating between two or more rollers. Factors that influence particle motion on an inclined conveyor belt and which were considered in the selection of some of the design parameters include, friction between the particle and belt, gravity, particle shape, angle of inclination of the belt, and the speed of conveyor. Figure 3 is a sketch showing the main forces influencing motion on the belt.

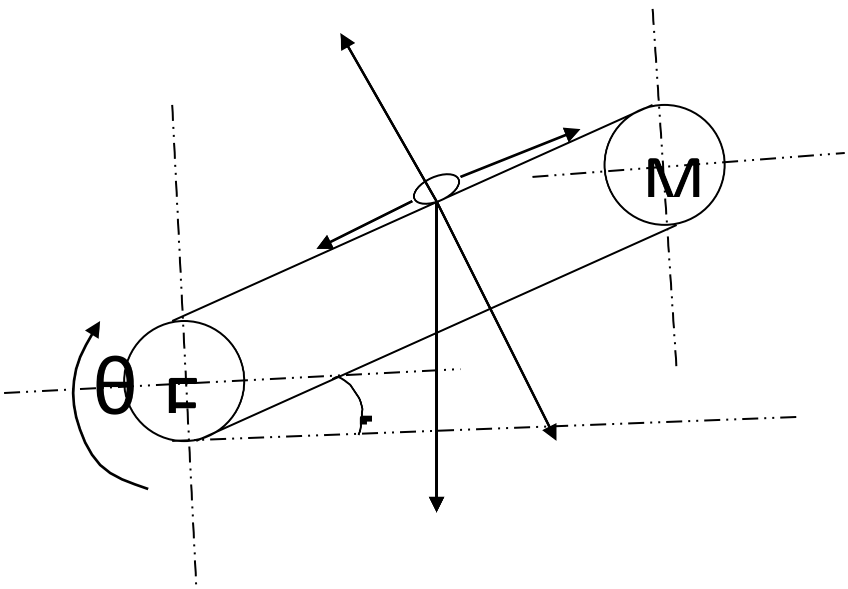


Figure 3: Sketch of Forces on a particle on a conveyor

A key principle behind the use of a belt conveyor for separation of agricultural materials is that rolling friction is less than sliding friction. Thus it was anticipated that on an incline conveyor belt, kernels by virtue of their rounded shape roll thereby exhibiting rolling friction while shells slide making sliding friction the predominant factor in their motion. As the shells slide, and depending on the nature of the surface involved, and the angle of inclination some of the shells get stuck on to the belt and are carried along. Table 1 shows different levels of friction for shells and kernels which are the two main constituents of interest to the design on three different belt materials. It may be deduced from the table that jute is the material that provides the widest difference in friction for kernels and shells followed by tarpaulin. However, tarpaulin will provide the necessary material strength required and was selected for the design.

Table 1: Friction angles between components and various belt materials

COMPONENT	TARPUALIN	NYLON	JUTE
Kernels	32.8	20.3	35
Shells	40.3	25.5	48

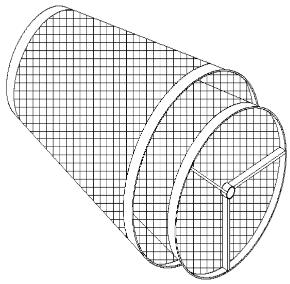


Figure 4: Conceptualized Sketch of the two-ply sieve

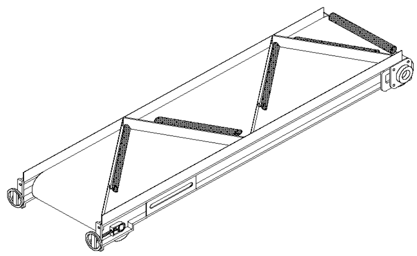


Figure 5: Conceptualized sketch of a conveyor

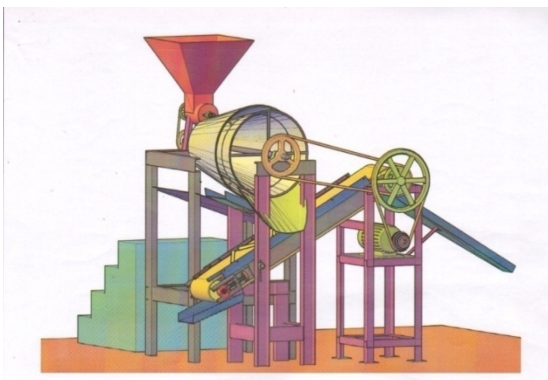


Figure 6: A 3D impression of the separator

3.0 Results and discussion

3.1 Description of the separator

The mechanized Palm Kernel-Shell Separator has two major component units of equipment which are a two-ply rotary screen, and an inclined belt conveyor. These components were designed and fabricated as one unit and run by a single motor. It could also be driven by a diesel engine, which is the commonest source of power at the Krammers. The rotary screen is a two ply rotary sieve obtained from a wire mesh rolled with a taper to make an inner and outer screen. This screen assembly is mounted on a shaft with spokes through which power is transmitted. The rotary screen serves as a cleaning device meant to remove all the debris and fine particles while at the same time separating the cracked mixture into size ranges. During operation, the sieve is fed with cracked palm nuts mixture through a hopper. Below the hopper, there is an auger which serves as a metering device to control the quantity of material that is fed into the inner sieve of the two ply sieve. Materials with particle sizes less than 10 mm pass through the screen aperture and are deposited on the outer sieve. Oversize materials travel along the sieve and are collected separately. The outer sieve retains materials that are larger than 5 mm in size and these are deposited directly on to the belt conveyor assembly where the actual separation takes place. The inclined conveyor belt has rollers mounted on it and also serves to facilitate the flow of kernels downstream while at the same time serving as an added source of restriction for the shells thereby minimizing the probability of them sliding down the conveyor.

The equipment is powered by a three phase 3 kilowatt (2 horse power) motor. A five horse power diesel engine could also be coupled onto the transmission system to provide the drive. The motor through a belt transmission system drives the conveyor, the sieve and also the metering device mounted at the throat of the hopper.

During operation, kernels rolls to the base while shells are taken up the incline and deposited at the opposite end. The main principle behind the use of a belt conveyor for separation of agricultural materials is that rolling friction is less than sliding friction. Thus on an incline conveyor belt, kernels by virtue of their rounded shape roll thereby exhibiting rolling friction. Shells on the other hand slide making sliding friction the predominant factor in their motion. As the shells slide, and depending on the nature of the surface involved, and the angle of inclination some of the shells get stuck on to the belt and are carried along.

3.2 Design Parameters

Key parameters of the two major components of the separator are shown in table 2

Table 2: Component parameters

TWO PLY SIEVE		
PARAMETER	Inner Sieve	Outer Sieve
Major diameter (mm)	650	700
Minor diameter (mm)	300	400
Length (mm)	990	800
Screen aperture (mm)	10	5
CONVEYOR BELT		
PARAMETER		
Length (mm)	2100	
Optimal Inclination	39°	
Optimal Speed (rpm)	40	

Other general parameters of the separator are:
Source of energy: Electricity or Diesel Engine
Power rating: 3-phase, 2hp/3kW Electric Motor/ 8 hp Diesel Engine
Capacity: 500 kg/Hr
Efficiency of separation: 85%
Overall dimensions

- Max Length : 3.0 Meters
- Max Width : 2.5 Meters
- Max Height : 2.6 Meter
- Max Weight : 3000 kg

Figure 7: Fabricated Palm kernel shell separator

4.0 Conclusion and Policy recommendation

A major breakthrough has been achieved through the successful design and fabrication of a mechanized palm kernel shell separator suitable for the small scale processors who constitute a very large proportion of processors in the oil palm industry. A successful dissemination of this technology to the key beneficiaries would go a long way to minimize the drudgery of operations, increase productivity and income levels.

By way of policy, it is recommended that the activities of the women in this industry should continue to be highlighted to emphasize the difficulties and unhygienic as well as environmentally unsuitable ways in which their activities are undertaken. The ministry of Food and Agriculture and NGO's operating in the agricultural sector could assist in organizing women into groups for possible assistance from financial institutions. Financial institutions on the other hand should be encouraged through favourable schemes to grant soft loans to women groups who are already operating in selected areas to be able to acquire the equipment.

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PALM OIL CONTAMINATION ASSOCIATED WITH ITS PROCESSING AND MARKETING: SOME PRELIMINARY FINDINGS

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Abstract

The oil palm (*Elaeis guineensis* Jacq.) ranks among the most important oil producing crops in Sub-saharan Africa. Oil palm produces one of the major oils and fats traded on the continent and the world today. Palm and palm kernel oils contributed 36.1% of the world's total oils and fats in 2007/2008. Small-scale processors producing crude palm oil account for 80% of total Ghana palm oil production. The vast majority of processors (80%) are women who are employed in this activity as wage workers. Production of palm oil and its marketing is constrained by quality problems some of which are deliberate. The most cited culprits are the palm oil sellers whom it is alleged contaminate the oil with Sudan IV. To discourage the widespread use of the major contaminants, Sudan IV, in Ghana, CSIR-Oil Palm Research Institute under sponsorship of COTVET through STEPRI has started training processors and palm traders on how to produce and market quality oil.

Two training programmes were organized for 50 processors and one awareness creation session was organized for 100 market women in the Greater Region. Palm oil samples were collected from the major markets in two Regions to test for FFA, Moisture Content Peroxide value and Sudan IV.
The free fatty acid (FFA) and moisture content (MC) of all samples collected from the various markets all exceeded the internationally accepted standards of ≤ 5% and ≤ 0.1% as recommended by Codex Alimentarius/FAO/WHO norms (2005). Peroxide values of samples from selected markets with the exception of Koforidua and Nkawkaw were below ≤ 15 meq KOH/g (Porim, 2011; Codex, 2005). There is contamination of palm oil with Sudan IV in some markets.

This calls for more training, awareness creation and surveillance by the mandated bodies.

Introduction

The oil palm *Elaeis guineensis* Jacq. ranks among the most important oil producing crops in Sub-saharan Africa, and is one of the most important sources of edible oil. The oil palm belt in Africa runs through the southern latitudes of Guinea, Sierra Leone, Liberia, Ivory Coast, Ghana, Togo, Benin, Nigeria, Cameroun, and into the equatorial regions of Equatorial Guinea and the Congo.

In Ghana, palm oil and palm kernel oil represent 2% of total agricultural production value chain in 2010 (MOFA, 2012).

The cultivation of oil palm in Ghana is dominated by private small-scale farmers who cultivate about 80 % of the estimated total land area of 305, 758 hectares under oil palm cultivation. The areas defined by van der Vossen (1969) as suitable for oil palm cultivation in Ghana are some areas of the six regions, including Volta, Eastern, Central, Western, Ashanti and Brong Ahafo. In Ghana, oil palm bunch production has a peak season in February-May and a lean season in September- December. This corresponds to the rainy and dry seasons. About 70 percent of annual yield occurs in the peak season.

Palm oil processing is an important economic livelihood activity among rural dweller, especially women and the landless poor in the forest areas. Small scale processors produce about 80% of total Ghana palm oil (MOFA, 2012)
A number of small scale processing mills involved in extracting oil from oil palm and are scattered in the oil palm growing areas where a lot of people especially women and the aged make their livelihood (Opoku and Asante, 2008; Adjei-Nsiah *et al*., 2012; Osei-Amponsah *et al*., 2012).

A typical artisanal mill can employ about 30-50 people. Such jobs created in the rural areas help stem the rural-urban drift and contributes to the socio-economic development of the rural areas where the crop is variously produced and processed.

The vast majority of processors produce poor quality oil and this type of palm is not acceptable to local, industrial and export markets because it affects the efficiency and cost of refining process (Gibson et al., 2007).

Crude palm oil is made up of glycerides (i.e. tri, di and mono)(Akinola *et al*., 2010) of fatty acids, phosphatides, unsaponifiable constituents and free fatty acids. Crude palm oil has the unique character of having balanced saturated (45% palmitic acid and 5% stearic acid) and un-saturated fatty acids (40% oleic acid and 10% linoleic acid) (Lai *et al*., 2012). This high content of saturated fatty acids is responsible for its semi-solid state at room temperature. Crude palm oil is naturally orange-red to yellowish-brown owing its colour to the high content of carotenes (Ng and Choo, 2016).

Crude palm oil produced from such traditional and small-scale processors has in recent times been in high demand, so much that it is traded on the export market due to its better sensory qualities (i.e. smell, taste and color). However, such crude palm oil is plagued by the reports of low quality as reported by authors such as Coursey (1966); Broadbent and Kuku (1977); Aletor *et al.* (1990); Mensah (1999) and Tagoe *et al.* (2012).

Contamination of crude oil with colorants such as sudan iv has also been reported by Food and Drug Authority (FDA) in Ghana in 2015 (Daily Graphic online, 30th October & Nov 4, 2015)

Oil quality is an important attribute of palm oil from the perspective of trade and with the continued demand of quality improvement from consumers; producers are continuously required to improve upon production techniques and methods. Quality of palm oil is generally graded by free fatty acid content, moisture content, dirt content, peroxide value and the absence of contaminants (Aletor *et al.*, 1990; Akinola *et al.*, 2010; Ohimain *et al.*, 2012).

The urge to produce more palm oil products and earn more income through marketing has brought in its wake issues on palm oil quality from the artisanal level through to marketing.

For the millers and processors, certain best practices are not followed or ignored in their haste to process more palm oil which eventually affect the palm oil quality produced (Zu, *et al.,* 2012). The problem is compounded by some palm oil traders who do introduce contaminant (Sudan IV) into the palm oil before purchase from the millers and processors or deliberately add the Sudan IV to the palm oil purchased to create product conditions which are attractive to consumers. What is clear in these transaction is that both the palm oil sellers and producers/ processors are not aware of the harmful effect of Sudan IV on human health.

It is in the light of this contamination issues, which appear to be widespread, that CSIR-STEPRI secured COTVET sponsorship for CSIR-Oil Palm Research Institute (CSIR-OPRI) to run a project to improve the quality of palm oil produced at the artisanal level and to create awareness on the dangers of Sudan IV in palm oil and the effect on human health. The objective is to improve the palm oil quality and to discourage sellers especially from adding Sudan IV into oil palm they sell on the market.

Methodology

The project consisted of two broad activities. The first being training of artisanal palm oil processors on Best Palm Oil Processing Technology for production of quality palm oil, awareness creation on palm oil contamination, to processors and palm oil sellers to discourage deliberate contamination. The second is laboratory analysis to check on the quality of palm oil on selected markets and the extent of Sudan IV contamination in the oil.

Two trainings were organized for Fifty (50) artisanal palm oil millers, processors, and three (3) Agricultural extension Agents in the Kwaebibirem and Denkyembour Districts of the Eastern Region of Ghana.

The trainings were done on the 4th and 11th of May 2016 at Kade and Abodom respectively. The participants were randomly selected from six communities in the two districts. The selected communities are areas where active palm oil processing activities are done with a large numbers of processors.

The training focused on best processing practices and palm oil contamination. The aim was to equip the processors with requisite knowledge and skills to produce quality palm oil for consumption. The training also sought to educate them on the description and the effects of Sudan IV, and to encourage them not to connive with market traders to deliberately contaminate processed palm oil with it. The teaching methods employed involved PowerPoint presentations, practical demonstration and discussion on palm contaminants, its effects on human health and legal issues on the use of Sudan IV. The medium of communication were English and Twi as these languages are commonly used by the processors.

Each training session lasted a little over four hours. The resource persons were from the CSIR-Oil Palm Research Institute.

An awareness creation on palm oil contamination with special reference to Sudan IV was organized for palm oil traders in the Greater Accra Region on the 5th of July 2016 at the Madina market in Accra. The programme was organized by the CSIR-OPRI in collaboration with the Oil Palm Development Association of Ghana (OPDAG) with an official from Food and Drug Authority (FDA) also attending as a resource person. The other resource persons were from the CSIR-Oil Palm Research Institute and the Oil Palm Development Association of Ghana. In order to widely publicise the programme, ten media houses; both print and electronic, were invited. About 100 palm oil traders from the major markets in Accra attended the programme. The activities took three hours in the form of open talk by the resource persons on:

1. Sudan IV and the dangers it poses on human health.
2. Good palm oil storage for marketing.
3. The law and Sudan IV palm oil contamination.

This was followed by an open forum for the participants to ask questions on the issues on board and also to contribute to the programme. There were interactions with the media also. The medium of communication was Twi.

The second part of the project consists of sampling palm oil from some market centres in the Eastern and Ashanti Regions to check on palm oil quality and Sudan IV contamination. Fifteen market centres were visited for sampling in both regions.

Sampling market sites

Samples were collected from the Eastern and Ashanti regions. In the Eastern Region, samples were purchased from the markets of the following towns; Oda, Nkawkaw, Koforidua, Asesewa, Adawso, Adeiso, Asamankese and Kade: in the Ashanti Region, the following markets were sampled; Tafo, Tanoso, Ejisu, Asafo, Atonsu, Santasi, and Fumso.

From each market, a 250 ml sample of crude palm oil was purchased from five randomly selected palm oil sellers at each market mentioned above. Samples were collected in 250 ml plastic bottles, capped and labelled with sellers' name, market and estimated age of oil.

Palm oil sampled from the various marketing centres was analysed at the Institute's laboratory for Free Fatty Acid, Peroxide Values and Moisture content. The samples for analysis of Sudan IV were sent to Food and Drug Authority Laboratory for analysis in Accra.

Procedure for analysis

All sample preparation procedures were according to A.O.A.C 17th edition, 2000 official methods 981.11

Preparation of oil for analysis

Samples were melted by immersing them in hot water in water bath until, it all melted thoroughly. Bottles were inverted severally to release all sediments from walls and bottom of container, and ensure uniform distribution of constituents throughout oil. Sample bottles were then uncapped.

Acid value and FFA analysis

A 2.5g sample of prepared oil was weighed into 250ml conical flask, 50 ml of fresh neutralized hot absolute ethanol and 1 ml phenolpthalein indicator solution added. The mixture was boiled for about 5 minutes and titrated while hot against standardized 0.5N sodium hydroxide solution.

Acid value was deduced by $= 56.1VN/W$

And Free Fatty acid by $= 28.2VN/W$

Where V= volume of titrant (standardized sodium hydroxide)

N=Normality of titrant (standardized sodium hydroxide)

W= Weight of sample oil.

Result and discussion

Fifty (50) processors and 100 palm oil traders were trained. The pictures below (Plates 1-4) show the training of the palm oil, processors, market women, contaminated palm oil with Sudan IV sample and resource persons from CSIR-OPRI, OPDA and FDA.

The training exposed the processors to understand how to process quality palm oil by reducing storage time below 5 days when they receive fresh fruit bunches from the field, operate on clean floor and environment, begin the processing promptly, avoiding over boiling and under boiling of fruits, avoiding dirty environment and avoiding the introduction of Sudan IV into the processed palm oil.

Plate 1.Training of millers and some processors with some extension officers in attendance

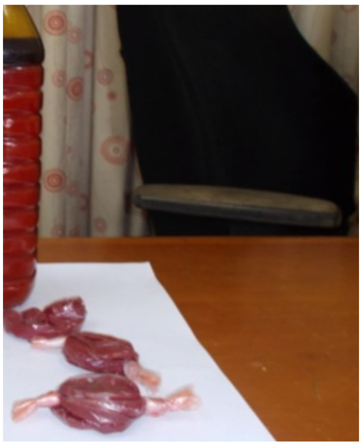

Plate 2. Awareness creation at the Medina market.

Plate 3. Samples of Sudan IV and contaminated oil.

Plate 4. Resource persons at the market.

The physiochemical parameters of the crude palm oil sampled from the various markets are presented in figures 1-3 and Sudan IV contamination in Table 1.

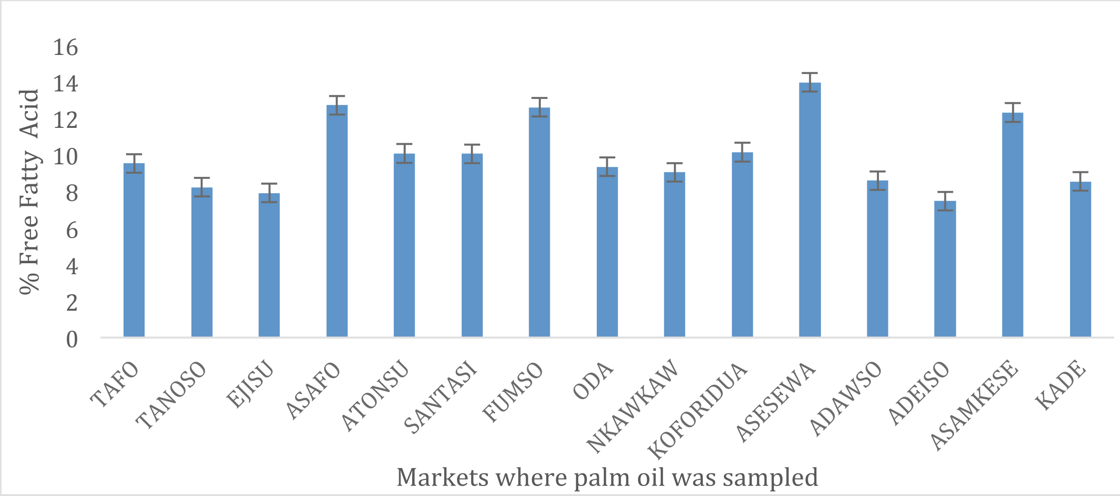

Fig. 1. Free Fatty Acid of crude palm oil sampled from selected markets

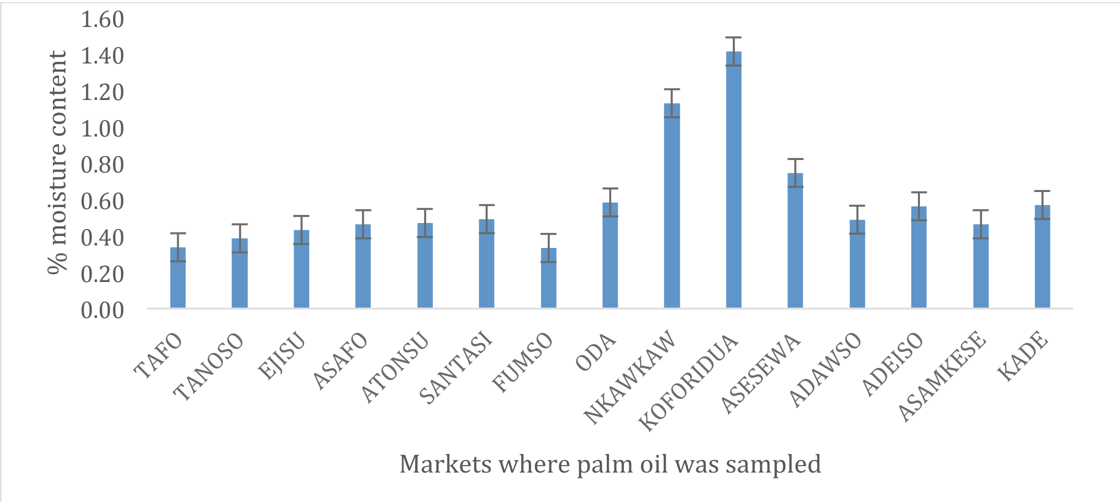

Fig. 2. Moisture content of crude palm oil sampled from selected markets

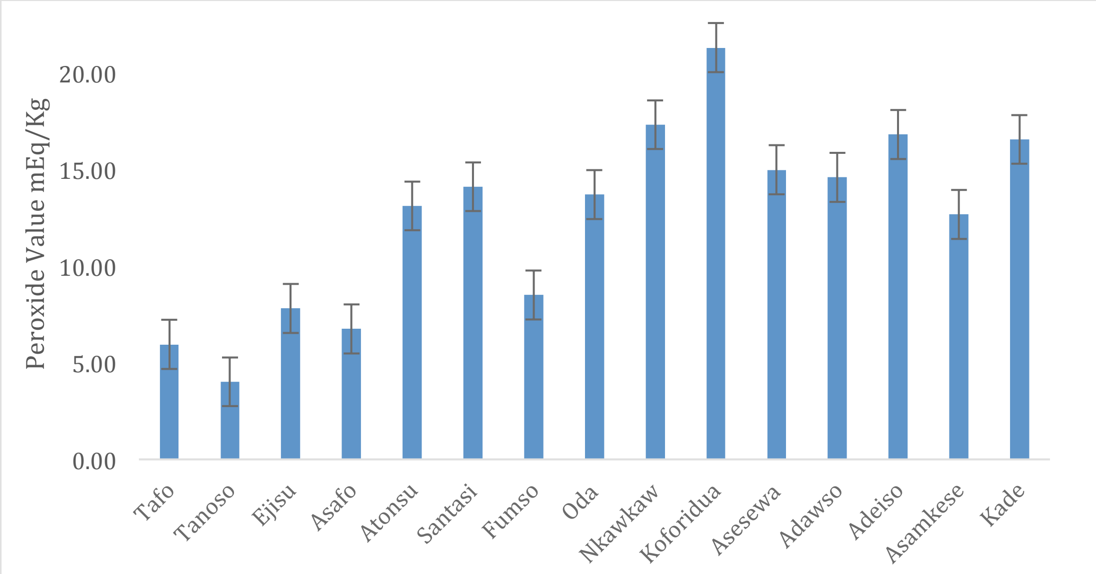

Fig 3. Peroxide value of crude palm oil sampled from selected markets

Quality of crude palm oil deteriorates mostly by hydrolysis and oxidation (Anon, 2004). Therefore the extent of physical and chemical deterioration are best measured by physico-chemical parameter that measure the resultant products of the hydrolysis, splitting of the triglyceride molecule at the ester linkage, producing short-chained free fatty acids. Primary and secondary lipid oxidation produces hydroperoxides, which may further generate aldehydes (Anon, 2004; Akinola *et al.*, 2010). The products of lipid oxidation and hydrolysis are characterized by some disagreeable odours and flavors usually associated with rancidity. The extent to which an oil undergoes primary oxidation or first-phase rancidity is primarily estimated by peroxide value and the quantities of short-chained free fatty acid estimated by the free fatty acid test (Kirk and Sawyer, 1991). Moisture content estimates the amount of water available to facilitate lipid hydrolysis, oxidation and support microbial growth. Dirt content estimates the insoluble matter in the oil.

The free fatty acid (FFA) and moisture content (MC) of all samples collected from the various markets all exceeded the internationally accepted standards of ≤ 5% and ≤ 0.1% as recommended by Codex Alimentarius/FAO/WHO norms (2005). Peroxide values of samples from selected markets with the exception of Koforidua and Nkawkaw were below ≤ 15 meq KOH/g (Porim, 2011; Codex 2005). The high FFA and MC result confirms the poor quality of crude palm oil supplied to Ghanaian local markets by artisanal processors as indicated by authors such as Tagoe *et al* (2012), Vissoh *et al*.(2010) and MASDAR(2010). Low peroxide values (Chong *et al*.,2008) are an indication of the freshness of crude palm oil (CPO) and suggests that rancidity hadn't set in yet (Harold *et al*., 1981). Odour and unpleasant tastes, characteristic of rancidity mostly begins to be noticed when the peroxide values exceed 20mEq/Kg (Harold *et al*., 1981; Ekwenye, 2006).

The high FFA, MC and mostly low PV of most samples from selected markets indicate that, the observed low quality is probably due to deficiencies in processing methods and probably longer storage time. It has been demonstrated by various authors such as Albert et al.(2011) that crude palm with low FFA and MC suffers little deterioration during storage even up to a few months. Therefore, a significant improvement in crude palm oil qualities available on local markets will be realized if artisanal processors are educated, trained and incentivized to process quality crude palm oil free of any contamination.

The result from the analysis of oil for Sudan IV from the various markets are as shown in Table 1.

Table 1. Sudan IV contamination from selected markets in Ashanti and Eastern Region

Market	Contamination Level (%)
Tafo	**
Tanoso	Nil
Ejisu	Nil
Asafo	Nil
Atonsu	**
Santasi	Nil
Fumso	*
Oda	Nil
Nkawkaw	*
Koforidua	*
Asessewa..	*
Adawso..	Nil
Adeiso..	Nil
Asamankese…	*
Kade..	Nil
Trainees…	Nil

**Means contaminated market*

The result from the analysis of oil for Sudan IV from the various market shows the extent of how widespread the contamination is in the country and the role being played by the market sellers. This confirms the Daily Graphic News on reported cases of Sudan IV in palm oil by the Foods and Drug Authority in 2015. (Daily Graphic online,30th October & Nov 4, 2015).

Conclusion

The Project though preliminary has shown that more needs to be done for processors to improve the quality of palm oil produced in the country especially in the area of reducing FFA and moisture content. For the market women, the awareness creation was well received and appreciated. Of particular interest was the health issues that Sudan IV can cause to human health and the policing of the markets by Food and Drug Authority to arrest offenders who use Sudan IV in palm oil. The market women were encouraged to stop using the contaminants in palm oil to attract customers. There is widespread contamination of palm oil with Sudan IV at some markets.

Recommendation

More funding is needed to spread the training and awareness creation to other regions especially the Volta, Central and Western Region where palm oil processing and marketing are major activities. More awareness creation on Sudan IV to market women will help put a stop to the use of the contaminant in palm oil and make the use of palm oil safe for consumption in households. More surveillance should be done by mandated institutions to curb the problem

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HYDROLYSIS AND FERMENTATION OF GHANAIAN GREEN SEAWEEDS FOR BIOETHANOL PRODUCTION

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Abstract

The glucose content of *Ulva fasciata and Ulva flexuosa* along the coast of Ghana were investigated for bioethanol production potential. This study compares the hydrolytic performance of sulphuric acid (SA), Trifluoroacetic acid (TFA) and enzymes on green seaweeds for bioethanol production. At the same concentration of biomass for acid hydrolysis, SA gave higher percent glucose yields than TFA but acid hydrolysis in general gave more glucose than enzymatic hydrolysis. The percent glucose ranged from 8.7±0.02 % dw to 32.4±0.03 % in *Ulva fasciata* and from 13.5±0.03% to 23.0±0.10 % dw in *Ulva flexuosa.* Hydrolysates from the SA hydrolysis for both *U. fasciata and U. flexuosa* were spiked with 1%, 5%, and 10% glucose and complemented with urea for the growth of *Saccharomyces cerevisiae* at 32 °C and pH 4.8 and the weight loss was monitored. From after 24 hrs to 4 days of fermentation of 20 ml hydrolysate *U. fasciata* and *U. flexuosa* respectively ethanol yield increased from 2.39±0.15 g/L to31.6±1.06 g/L and 2.67±0.16 g/L to 39.1±0.27 g/L. The findings of this study thus support that green seaweeds from the coast of Ghana is a potential feedstock for bioethanol production. However, further research needs to be conducted on the enzymology of seaweed biomass to ensure a mild, cost effective and more convenient way of obtaining free glucose from the chlorophyta for bioethanol production in Ghana.

Key words: enzyme, hydrolysis, fermentation, bioethanol, seaweeds, glucose, *ulva* species

Introduction

Seaweeds are multicellular, macroscopic algae, abundant in coastal environments, especially when there is suitable substrate for attachment (Murphy et al, 2013). The macro-algae or seaweeds have been classified into three groups: brown (Phaeophyceae), red (Rhodophyceae), and green (Chlorophyceae) (Wei et al., 2013). Approximately 200 species of seaweeds are common to Ghana (Bolton et al, 2003). Seaweeds as a source of polysaccharide matrix have received attention from researchers across the world and have shown a very wide use in medicine, food and the production of bio-based substances for man's energy needs.

Problem statement

Ghana holds a potential in seaweed cultivation with 200 species of seaweeds available along the 540 km stretch of Ghana's coastal line coupled with shallow shorelines. It has not been reported of the use of seaweeds as food, for medicinal purposes or processed in any form in Ghana and up to date no appreciable use has been found for it. In Ghana seaweeds are washed ashore naturally. They get rotten at the seashore while mixed up with other debris from the sea causing serious environmental nuisance to communities along the coast and tourists in particular.

This situation is basically unacceptable to the scientific community and especially so when there are advanced biotechnological processes to deal with such menace. There is therefore the need to seek scientific solutions to such a huge challenge of a very good seaweed potential in Ghana with minimal or no use found for it as yet. It is particularly important to hydrolyze the seaweed polysaccharides in the most cost effective way to ascertain its potential for bioethanol production to support Ghana's quest for alternative fuel.

The purpose of this research was preliminary; to hydrolyse the seaweed polysaccharides into glucose and convert the glucose generated as a result to ethanol by fermentation to evaluate the possibility of establishment of a seaweed biorefinery plant in Ghana. The current study is based on four Ghanaian seaweeds (*Ulva fasciata, Ulva flexuosa, Hypnea musciformis and Sargassum sp.)*. The study covers the hydrolysis of the seaweed biomass to glucose by a two-step strong Sulphuric acid hydrolysis, Trifluoroacetic Acid hydrolysis and enzymatic hydrolysis using the novel cellulase complex *Cellic Ctec2* from Novozymes, Denmark. The study also assessed the fermentation of the hydrolysate from the Sulphuric acid hydrolysis to ethanol using *Saccharomyces cerevisiae* (Baker's Yeast).

Objectives

The objective of the research was to answer the following research questions:

- Are there green seaweeds in Ghana for seaweed bioethanol production?
- Is the green seaweed from Ghana a potential feedstock for bioethanol production from enzymatic hydrolysis?
- How could the glucose generated by hydrolysis be fermented into ethanol?
- What amount of ethanol could be generated from the hydrolysates?

Literature Review

Green seaweeds (Chlorophyta) belonging to Ulvaceae (*Ulva* and *Enteromorpha* species) represent an important biomass widely available on rocks at the shorelines along the coast of Ghana. Among the chlorophyta, *Ulva fasciata* and *Ulva flexuosa* are among the commonest green seaweeds in Ghana. *Ulva flexuosa* subsp. pilifera also Enteromorpha pilifera was first time described as Enteromorpha but now used as a synonym for Ulva (Messyasz et al., 2013). *Ulva flexuosa* like *Ulva fasciata* (sea lettuce), belonging to the phylum chlorophyta is cosmopolitan specie that has a worldwide distribution in temperate and tropical waters. Thus, seaweeds in general have a huge occurrence in Ghana, 43.2 % of which are the green, 23.9 % brown and 32.9 % red (Branoff *et al.*, 2009). "*Ulva fasciata* is common edible seaweed in many parts of the world where it grows. It has a very fine texture and fresh taste and is often chopped into salads or used as a relish, though it can also be cooked and used in soups. Green algae extracts are also very nutrient rich and are a wonderful addition to natural cosmetic products. *Ulva fasciata* is known to be widely harvested in United States, Japan, and China and many parts of Asia. *Ulva fasciata* can be harvested by hand from wild stocks, being sure to leave the basal portion attached to the rocky attachments or substrates so that the plant can re-grow.

Seaweeds have been generally reported to contain large amounts of polysaccharides, notably cell wall structural, but also myco-polysaccharides and storage polysaccharides (Murata and Nakazoe, 2001; Kumar et al., 2008). There are several features that make seaweeds, notably glucose-rich green seaweeds, excellent candidates for renewable bioethanol applications: Seaweeds have higher photon conversion efficiency and can synthesize and accumulate large quantities of carbohydrate (polymers) biomass for bioethanol production (Jensen et al. 2013).

Among the polymers synthesized by these seaweeds, cell wall polysaccharides represent around 38-54% of the dry algal matter. Chemical characterisation of polysaccharides in *Ulva or Enteromorpha sp* has been well researched into (Lahaye, 1991; Lahaye & Robic, 2007; Lahaye et al., 1995; Ray, 2006). Trung et al, (2013) considers the green seaweed (*Ulva spp),* as the most important prospect for cell wall polysaccharides estimated around 38-54% of the dry matter, although the *Enteromorpha species* was found to be very rich in carbohydrate with levels being as high as 70%-72%. Arasaki & Arasaki (1983) reported carbohydrates composition of seaweeds to comprise 50–60% of the dry weight in general perspective and indicated that soluble carbohydrates ranged from 4.5–39.9% dw. McDermid & Stuercke (2003) were very specific of the soluble carbohydrate composition among the Chlorophyta with *Enteromorpha flexuosa* having the highest value of 39.9% soluble carbohydrates although Kennish & Williams (1997) reported lower (8.1–33.7%) soluble carbohydrates values. Reed (1907) further reports the non-fiber carbohydrate content of *Ulva fasciata*, one of the green seaweeds to be 50.6 %. Sung-Soo et al (2012) estimated the carbohydrate content of *U. pertusa,* one of the green seaweeds, as 59.07 % and suggested that the *U. pertusa* has the best conversion ratio of 91.46 % and *U. fasciata,* has cellulose composition of up to 15 ± 2.3% on dry weight basis (Trivedi et al., 2013). Research has shown that the chemical compositions of seaweeds vary as a result of geographical distribution, seasons and the environmental factors such as: water temperature, salinity, light, nutrients and minerals availability (Masutani and Yoza, 2011).

From the discussions above seaweed biomass comprises carbohydrates and mainly glucose, galactose and mannose are present as monomer units. The polysaccharides present are capable of undergoing Chemical, enzymatic or microbiological hydrolysis to produce the component monosaccharides such as glucose.

Methodology

Seaweed collection

Four species of seaweed: *Ulva fasciata, Ulva flexuosa, Hypnea musciformis and Sargassum sp.* were collected from the shorelines of Prampram in the Greater Accra region of Ghana for analysis. *Ulva* was further used in bioethanol fermentation trials. The samples were collected after they were washed-ashore at low tides.

Table 1: Investigated seaweed samples and sample location

Seaweed	Harvest date	Location (Ghana)	Coordinates	Location	Fermentation
Hypnea musciformis	2015-May-20	Prampram,	5.70N;0.11E	Shoreline	None
Ulva fasciata	2015- May-20	Prampram,	5.70N;0.11E	Shoreline	Test
Ulva flexuosa	2015- May-20	Prampram,	5.70N;0.11E	Shoreline	Test
Sargassum sp.	2015- May-20	Prampram,	5.70N;0.11E	Shoreline	None

Sample preparation

Samples were washed several times with milli-Q water, frozen at -20 °C and freeze dried (-57 °C), grinded to homogenous powder (about 0.5 – 1 mm sieve pore), stored in air tight glass jars and kept at 4°C for chemical analysis. All chemical analyses were carried out in triplicates.

Total solids, moisture and ash content analysis

The methods recommended by Sluiter et al., 2008 were used in the analysis of Total Solids and ash content. Approximately 0.5 g of seaweed samples were weighed into pre-weighed oven-dried aluminium weighing-dishes and placed in an oven maintained at 105 ± 3 °C overnight. The dishes together with the samples were cooled in a desiccator and weighed. Percentage Total Solids were calculated as follows:

$$\%Total\ Solids = \frac{Weight_{dry\ pan\ plus\ dry\ sample} - Weight_{dry\ pan}}{Initial\ Weight_{Sample}}\ X\ 100\%$$

$$\%Moisture = 100\% - \%Total\ Solids$$

The ash content analysis was determined by heating the dried sample in an oven at 550 ± 5 °C for 3 hours, followed by cooling and weighing. The ash content was calculated as follows:

$$\%Ash\ Content = \left(\frac{Weight_{dry\ pan\ plus\ ash} - Weight_{dry\ pan}}{Weight_{dry\ sample}}\right) X\ 100\%$$

Two-step Sulphuric acid hydrolysis

Sulphuric acid hydrolysis method (SAH) was carried out according to the method of Sluiter et al (2011). Four treatments (Ufa, Ufl, Hm, SG), besides a pure glucose sample (SP) as a positive control, were prepared into homogenous form (0.5 - 1 mm) and the mass of the sample weighed into a pyrex tube on dry matter basis. In the first step, 72 % H_2SO_4 solution was prepared by dissolving 132.8 ml of 96 % H_2SO_4 in mQ water in a 200 ml volumetric flask. The samples were treated with 1.5 ml of these 72 % H_2SO_4 solution in pyrex tube. However, 0.504 ml of the glucose sample as a positive control was treated with 0.996 ml of 96 % H_2SO_4 to make a total volume of 1.5 ml. Hydrolysis was carried out at 30 °C for 1 h in a shaking water bath at 150 rpm with periodic stirring with a glass rod. In the second step the concentration of the sulphuric acid was reduced to 4 % by adding 42 ml of milli-Q water to each tube and autoclaved for 20 minutes, cooled and filtered in a pre-weighed glass crucible (size 4). The hydrolysate was collected into a 50 ml falcon tube for glucose content analysis and the residue was dried at 105 °C overnight and weighed. This was repeated for 40 and 60 minutes.

TFA hydrolysis

The seaweed biomass was hydrolysed according to Arnous and Meyer (2008) with some modifications. Five millilitres (5ml) of 2M Trifluoroacetic acid (TFA; EUPAC name = 2,2,2-Trifluoroethanoic acid) was added to 17.25 mg of seaweed biomass on dry matter bases in a TFA-cap tube. Each tube was tightly sealed and hydrolysed at 121 °C for 2 h in a drying oven. After hydrolysis the tubes were cooled under the fume hood. Five hundred microlitres (500 µl) of the hydrolysate was transferred into an Eppendorf tube for D-Glucose-Hexokinase Assay Analysis. The rest of the hydrolysates were lyophilized and kept at -20°C until HPLC analysis.

D-Glucose-Hexokinase Assay Procedure

Hydrolysates from SA, TFA and enzymatic hydrolysis were subjected to the D-glucose-HK microplate (96-well flat bottom plate: corning) assay procedure (HK/G6P-DH format) adopted by Megazyme. Two hundred microlitres (200 µl) of mQ water was measured into the 96 microplate well and 10 µl of the hydrolysate were added together with 10 µl of both solution I (buffer) and II (NADP+/ATP). This was repeated for glucose standards on the same plate. A blank well consisting of 210 µl mQ water also received solution I and II. The content of the plate was mix for 30 s and absorbance of samples, blank and standards were read at 340 nm and recorded as A1. Two microlitres (2 µl) of suspension 3 (HK/G-6-PDH) was added to all the wells and the absorbance at 340 nm was read the second time and recorded as A2. The difference in absorbance was compared to the standard without the blank and the concentrations of the samples were extrapolated and converted into percentage glucose using the formula below:

$$\%Glucose = \left\{\frac{y - (y\_intercept)}{slope}\right\} \times DF \times (HF) \times IC\ x\ 100$$

Where: DF – Dilution factor, HF – hydration factor and IC – Initial concentration

HPLC Analysis

Prior to analysis by HPAEC-PAD, the hydrolysates were re-dissolved in 4.5 ml of mQ H_2O. Just before injection for HPAEC analysis each hydrolysate was filtered through a 0.22 µm GH Polypro Acrodisc® filter (Pall Life Sciences, Ann Arbor, USA). Recovery values of the monosaccharides were estimated by exposing a mixture of monosaccharide standards (l-(+)-fucose, l-(+)-rhamnose, d-(−)-arabinose, d-(+)- galactose, d-(+)-glucose, d-(+)-xylose, d-(+)-mannose, d-(−)-fructose, and d-(+)-galacturonic acid) to the acid hydrolysis conditions stated above. The monosaccharide recovery values were expressed in percentage of the initial addition level and were used as correction factors for the quantitative monosaccharide assessment by acid hydrolysis.

Enzymatic Hydrolysis

The enzymatic hydrolysis was carried out according Dirk et al. (2015) with slight modifications. An aliquot equivalent to 20 mg of seaweed in a 1.5 ml Eppendorf tube was stirred with 0.9 ml of 50 mM sodium acetate buffer (pH 5.0) and then extracted with 1 %, 2 %, 5 % and 6 % enzyme concentration for 1 hr. The optimization of enzymatic hydrolysis of biomass was carried out for enzyme dosage, incubation period and enzyme: substrate ratio. Commercial cellulase enzyme (*Cellic Ctec2*) from Novozyme, Denmark was employed for biomass hydrolysis. Dried algal powder (20 mg) was hydrolyzed with different concentration of cellulase from 1%, 5% and 10% w/v in a fixed volume (1 mL) of 50 mM sodium acetate buffer (pH 5.0) and incubated for 0, 4 and 24 h at 50 °C on an orbital shaker with a speed of 150 rpm. Hydrolysis was deactivated at 100 °C for 10 minutes on a hot plate (Thermomixer Comfort, Eppendorf) after an interval of 4 h, cooled and centrifuged at 10,000 rpm for 10 minutes at room temperature and the supernatant collected. The reducing sugar, glucose, was measured spectrophotometrically following the D-Glucose-HK assay procedure.

Fermentation of glucose to ethanol

Fermentation of glucose to ethanol was carried out according to Anders et al., 2011. Fifty millilitres (50 ml) blue cap flasks containing 20 ml of Millipore water and 1 %, 5 % and 10 % D-Glucose, respectively, in duplicates were used for the fermentation. Two hundred microlitres (200 µl) of 24 % Urea was added to each flask including the control to boost the nitrogen content of the mixture. Baker's yeast (*Saccharomyces cerevisiae)* of 0.200 g was added to the content of each flask after which the yeast locks filled with 2 ml glycerol were put on each flask. The flasks were weighed and put in an incubator (Adolf Kuhner AG Schweiz, Lab-Therm) at 32 °C, with shaking at 90 rpm. The starting time was noted. Weight loss (Mx) was monitored during working hours to monitor the fermentation process.The first equation shows the formation of ethanol resulting in weight loss as CO_2 while the second shows the reaction for lactic acid formation, which does not give weight loss (no CO_2).

Ethanol formation: $C_6H_{12}O_{6\,(aq)} \rightarrow 2C_2H_5OH(l) + 2CO_{2(g)}$

Lactic Acid formation: $C_6H_{12}O_6 \rightarrow 2C_3H_6O_3$

Sulphuric acid hydrolysates (Ufa, Ufl) from 40 minutes autoclave time were defrosted and bulked according to the seaweed specie. Seaweed hydrolysate obtained after Sulphuric acid hydrolysis of 150 mg biomass was enriched with urea and spiked with (1 %, 5 % and 10 %) glucose. 40 µl/20 ml of urea (24% urea) was added to each bulk solution and the pH adjusted to 4.8 with 12 M NaOH. The theoretical weight of ethanol is calculated using the formula as derived below and based on the molar masses of ethanol (46.07 g/mol) and CO_2 of (44.01 g/mol):

$$Weight\ of\ ethanol = weightloss \times \frac{Mw(CH_3CH_2OH)}{Mw(CO_2)}$$

Statistical analysis

All measurements involving chemical compositional analysis of seaweed biomass were carried out in triplicates. Hydrolysis was run in triplicates and each triplicate was statistically analyzed in triplicates using the Minitab package (2000) for statistical analysis. The Analysis of Variance was tested at 5% confidence level and significant differences were noted using the p-values. Fermentation was measured in replicates and analysed using excel sheet. Reported values in this study were means with standard deviation. For data generated by UV spectroscopy, glucose linear standard curves were drawn and the glucose amounts were estimated thereafter.

Results

Total Solids, Moisture and Ash Contents of Selected Seaweeds

In order to examine the glucose content of some selected seaweeds, the chemical composition of the selected seaweeds were investigated. **Table 2** shows the Total solids (TS), moisture content (MC) and ash content (AC) of four different species of seaweeds from the coast of Ghana. The %TS was highest in *Ulva fasciata* (92.73 ± 0.26) % and least in *Ulva flexuosa* (83.78 ± 0.27) %. There was significant difference ($P \leq 0.05$) in Total solids among the seaweed species considered under this study. Tukey simultaneous multiple comparisons further established that the mean percentage total solids of the individual species were different. The percentage moisture content of the selected seaweeds is also presented in **Table 2.** The moisture content was significantly different ($P \leq 0.05$) among the seaweed species. The highest (16.22 ± 0.27%) and the least (7.27 ± 0.26%) moisture content were observed among the green seaweeds; *Ulva flexuosa* and *Ulva fasciata* respectively. The ash content of the seaweed species was also investigated before and after hydrolysis, the results of which are presented in **Table 2**. *Ulva flexuosa* had the highest (18.12±0.80%) ash content but left the second highest ash content

(4.57 ± 8.44%) after hydrolysis (unhydrolysed biomass). *Hypnea musciformis* which had the least ash content (12.53±0.27%) before hydrolysis also had the highest ash content (10.61 ± 2.06%) after hydrolysis.

Table 2: Determination of Total solids, moisture and ash in seaweeds and expressed as percent of freeze dried biomass

Seaweed	Type	Total Solids (%)	Moisture Content (%)	Ash Content (%)	Ash Content (%) UHB
U. fasciata	Green	92.73 ± 0.26**a**	7.27 ± 0.26**b**	13.18±0.86**c**	3.30 ± 0.95**d**
U. flexuosa	Green	83.78 ± 0.27**b**	16.22 ± 0.27**c**	18.12±0.80**d**	4.57 ± 8.44**a**
H. musciformis	Red	87.45 ± 0.10**c**	12.55 ± 0.10**d**	12.53±0.27**a**	10.61 ± 2.06**b**
Sargassum	Brown	91.05 ± 0.37**d**	8.95 ± 0.37**a**	16.51±0.80**b**	0.23 ± 0.38**c**

[1]Values are means ± standard deviations of triplicate determinations. Values with same letter(s) are not significantly different (p≥0.05)

Hydrolytic Potential of selected Seaweeds

Results of sulphuric acid hydrolysis, Trifluoroacetic hydrolysis and enzymatic hydrolysis of the biomass of *Ulva fasciata, Ulva flexuosa, Hypnea musciformis and* Sargassum were presented in**Table 3, 6, 7 and 8.** After hydrolysis and autoclaving for 20 minutes, the glucose content of the seaweeds after UV analysis ranged from 34.43±0.63 % in *Ulva fasciata* to 51.32±1.37 % in Sargassum. After hydrolysis and 40 minutes of autoclaving, the glucose content ranged from 21.22±0.59 % to 66.21±1.81 % in Sargassum and *Hypnea musciformis* respectively. When the autoclave time was increased for the hydrolysate, the amount of glucose, in percentage units, ranged between 48.24±5.04 and 74.21±0.49 in Sargassum and *Hypnea musciformis* respectively. The glucose amount was consistently different (P ≤ 5%) among the seaweed species and across the different times. The percent glucose content displayed little intra-specie variation except in *Ulva flexuosa* where the standard deviation was consistently high across the different autoclave times. Glucose values for *Ulva fasciata, Ulva flexuosa, Hypnea musciformis* and Sargassum from Trifluoroacetic hydrolysis (TFAH) are also presented in **Table 3.** The glucose generated as a result of TFAH ranged from 13.48±1.09 % to 17.36±2.67 % in *Ulva fasciata and Ulva flexuosa* respectively.

Table 3: Determination of glucose in *Ulva fasciata and Ulva flexuosa* by spectroscopy methods expressed in percentage

Sample	%Glucose from SAH at different autoclave conditions			%Glucose from TFAH
	H_2SO_4 hydrolysis, autoclave time in min at 121 °C			Autoclaved Time
	20	40	60	2 h
Ulva fasciata	34.4±0.6	50.40±1.48	64.33±1.33	13.48±1.09
Ulva flexuosa	40.2±2.3	44.12±3.97	73.13±1.63	17.36±2.67
Hypnea musciformis	40.7±1.9	66.21±1.81	74.21±0.49	15.12±1.57
Sargassum	51.3±1.4	21.22±0.59	48.24±5.04	14.00±0.66
Control	0.1±0.3	0.36±0.37	12.01±0.07	172.85±15.90

NB: Values are means ± standard deviations of triplicate determinations

The glucose content of the various seaweed species were validated by the use of the High Performance Liquid Chromatography (HPLC) and presented in **Table 4.** At 20 minutes autoclave time, the glucose content of the seaweeds by HPLC ranged from 8.68±0.02 % in *Ulva fasciata* to 46.46±0.05 % in *Hypnea musciformis*. At 40 minutes autoclave time, the glucose content ranged from 11.22±0.44 % to 31.31±0.03 % in Sargassum sp. and *Hypnea musciformis* respectively. When the autoclave time was 60 minutes, the amount of glucose ranged between 19.33±0.46 and 32.43±0.03 % in Sargassum and *Hypnea musciformis* respectively. The glucose content was consistently different ($P \leq 5\%$) among the seaweed species and across the different times. HPLC values for *Ulva fasciata* and *Ulva flexuosa,* from Trifluoroacetic hydrolysis (TFAH) are also presented in **Table 4.** The glucose generated as a result of TFAH ranged from 0.90±0.00 % to 1.80±0.01 % in *Ulva fasciata and Ulva flexuosa* respectively.

Table 4: HPLC analysis indicating glucose in *Ulva fasciata, Ulva flexuosa, Hypnea musciformis and* Sargassum sp. from SAH and TFAH as percentage of total biomass

Sample	%Glucose from SAH at different autoclave conditions			%Glucose from TFAH
	H_2SO_4 hydrolysis, autoclave time in min at 121 °C			Autoclaved Time
	20	40	60	2 h
Ulva fasciata	8.68±0.02	12.20±0.03	32.43±0.03	1.80±0.01
Ulva flexuosa	13.46±0.03	14.33±0.05	22.96±0.10	0.90±0.00
Hypnea musciformis	46.46±0.05	31.31±0.03	24.41±0.04	-
Sargassum sp.	32.40±1.41	11.22±0.44	19.33±0.46	-
Control	1.04±0.14	1.04±0.11	1.04±0.06	1.04±0.11

NB: Values are means ± standard deviations of triplicate determinations

The percent glucose content of seaweeds considered under this study was enzymatically hydrolyzed using *Cellic Ctec2* at different percentage concentrations and at different hydrolysis times. The results are presented in **Tables 5, 6 and 7.** After 1 h of hydrolysis at 1 % , 2 %, 5 % and 6 % enzyme – substrate concentration, the percent glucose content ranged from -1.05±2.18, -0.94±1.00, -1.92±0.41, -2.02±0.99 % to 11.70±3.38, 8.73±6.47, 6.77±0.91, 7.23±1.80 % in Sargassum and pure cellulose respectively. There was significant difference ($P \leq 0.05$) in glucose content across the different enzyme concentrations. Further simultaneous multiple comparison showed that the percent glucose from the pure cellulose was not comparable to the percent glucose from the other four seaweed species.

Table 5: Glucose from enzymatic hydrolysis at different E/S concentration for 1 h, 50 °C using pH 5 of 50mM sodium acetate buffer

Sample	Enzyme-Substrate concentrations			
	1%	2%	5%	6%
Ulva fasciata	1.82±1.07**a**	2.26±0.40**a**	0.76±1.39**a**	3.48±4.38**a**
Ulva flexuosa	2.19±0.70**a**	3.92±4.03**a**	0.87±2.39**a**	3.84±2.89**a**
Hypnea musciformis	1.96±2.38**a**	0.65±0.28**a**	0.61±1.82**a**	-0.40±1.86**a**
Sargassum sp.	-1.05±2.18**a**	-0.94±1.00**a**	-1.92±0.41**a**	-2.02±0.99**a**
Cellulose	11.70±3.38**b**	8.73±6.47**b**	6.77±0.91**b**	7.23±1.80**b**

NB: Values are means ± standard deviations of triplicate determinations

When the time for enzymatic hydrolysis was increased to 4 hrs. under and the E/S concentration was increased to include 10 % there was a marginal increase in the amount of glucose which ranged from 3.25±3.92 % to 20.08±2.09 % in 1% E/S concentration, 5.39±4.45 % to 9.08±2.98 % in 6 % E/S concentration in *Ulva flexuosa* and cellulose respectively, and 0.79±3.42 % to 12.52±1.00 % in 10 % E/S concentration in *Ulva fasciata* and cellulose respectively. The glucose content of *Ulva fasciata* and *Ulva flexuosa* were statistically comparable but both were not comparable to that of cellulose.

Table 6: Glucose from enzymatic hydrolysis at different E/S concentration for 4 h, 50 °C using pH 5 of 50mM sodium acetate buffer

Sample	%Glucose from EH at different E/S concentrations		
	Enzymehydrolysis, % concentrations at 50 °**C** pH 5 for 4 hours		
	1%	6%	10%
Ulva fasciata	3.91±2.20	7.09±1.13	0.79±3.42
Ulva flexuosa	3.25±3.92	5.39±4.45	1.75±2.45
Cellulose	20.08±2.09	9.08±2.98	12.52±1.00

NB: Values are means ± standard deviations of triplicate determinations

When the enzyme hydrolysis was monitored for 24 hrs, the amount of glucose generated from the *Ulvas (fasciata and flexuosa)* was still insignificant. The percent glucose ranged from 2.59±0.10 % in *Ulva flexuosa* at 10 % E/S concentration to 33.58±2.70 % in cellulose at 6 % E/S concentration. The percent glucose in the two green seaweeds of focus under this study was statistically similar but not comparable to that of cellulose.

Table 7: Glucose from enzymatic hydrolysis at different E/S concentration for 24 h, 50 °C using pH 5 of 50mM sodium acetate buffer

Sample	%Glucose from EH at different E/S concentrations		
	Enzyme hydrolysis, % concentrations at 50 **°C** pH 5 for 24 hours		
	1	6	10
Ulva fasciata	4.38±0.35	6.59±1.06	5.85±1.46
Ulva flexuosa	5.30±0.53	8.89±0.52	2.59±0.10
Cellulose	30.62±1.80	33.58±2.70	29.19±1.49

NB: Values are means ± standard deviations of triplicate determinations

Fermentation Potential of Hydrolysates from Selected Seaweeds

Sulphuric hydrolysate after 40 minutes of autoclave time was used in a fermentation process using the most commonly used fungal strain *Saccharomyces cerevisiae* synonymous to the term yeast. The resultant weight loss of the hydrolysate which was spiked with the same amount of glucose used in as positive control at three different concentration levels (1 %, 5 % and 10 %) was monitored and this is shown in **Figures 1-6** and **Table 8.** In less than 10 hrs. the yeast growth had reached the deceleration phase for both SA hydrolysate of *U. fasciata* (**Figure 2**) and *U. flexuosa* and glucose at 1 % glucose concentration. After 24 hrs. of fermentation the weight loss in the hydrolysate was lower as compared to the glucose at 1 % glucose concentration.

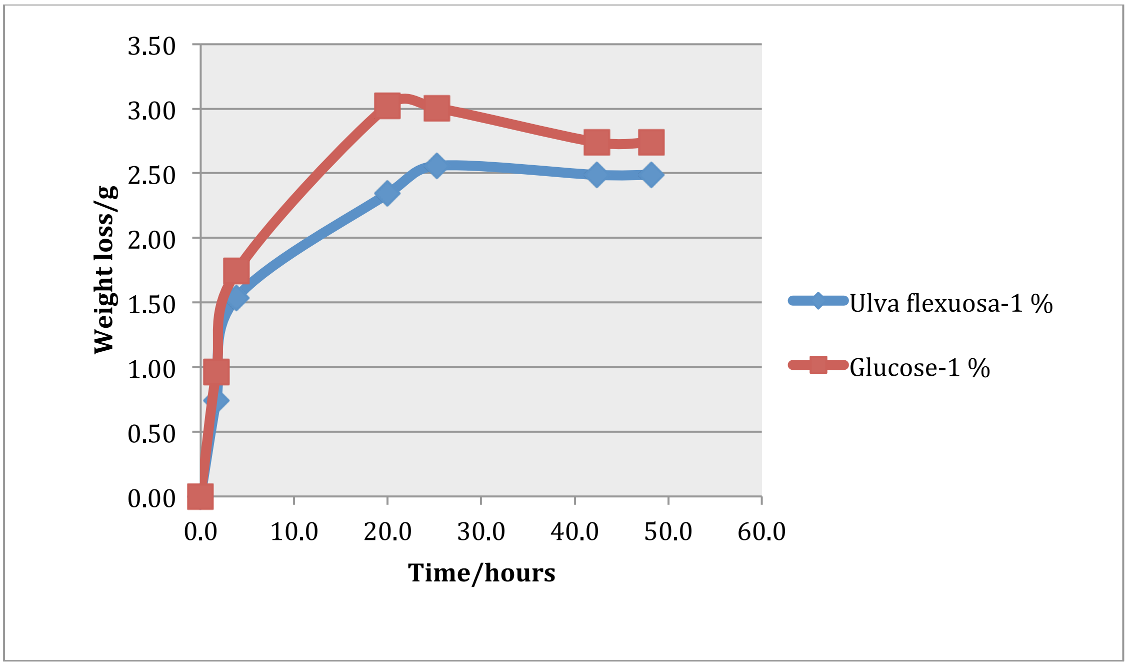

Figure 1: Comparison of weight loss in *Ulva flexusosa* hydrolysate (spiked with 1 % glucose) with 1 % glucoseat 32 °C in 20 ml fermentation flask after 48 hrs.

However, the weight loss was higher (2.56±0.15g/L) with *U. flexuosa* (**Figure 1, Table 8)** than (2.29±0.14 g/L) *U. fasciata* **(Figure 2, Table 8)** after 24 hrs. of fermentation for hydrolysate spiked with 1 % glucose. In both cases, the weight loss was lower than the 1 % glucose only (3.00±1.41 g/L) as shown in **Table 8.**

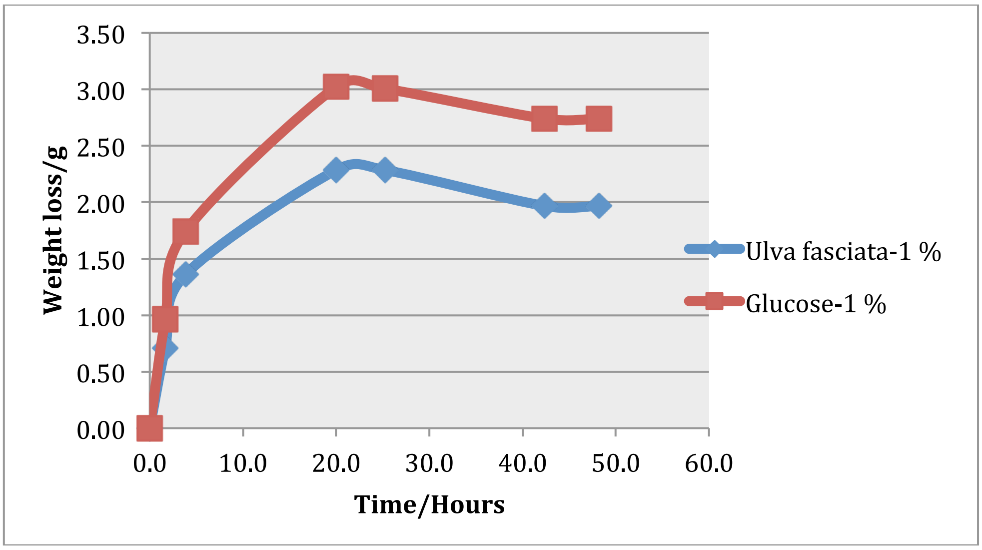

Figure 2: Comparison of weight loss in *Ulva fasciata* hydrolysate (spiked with 1 % glucose) with 1 % glucose at 32 °C in 20 ml fermentation flask after 48 hrs.

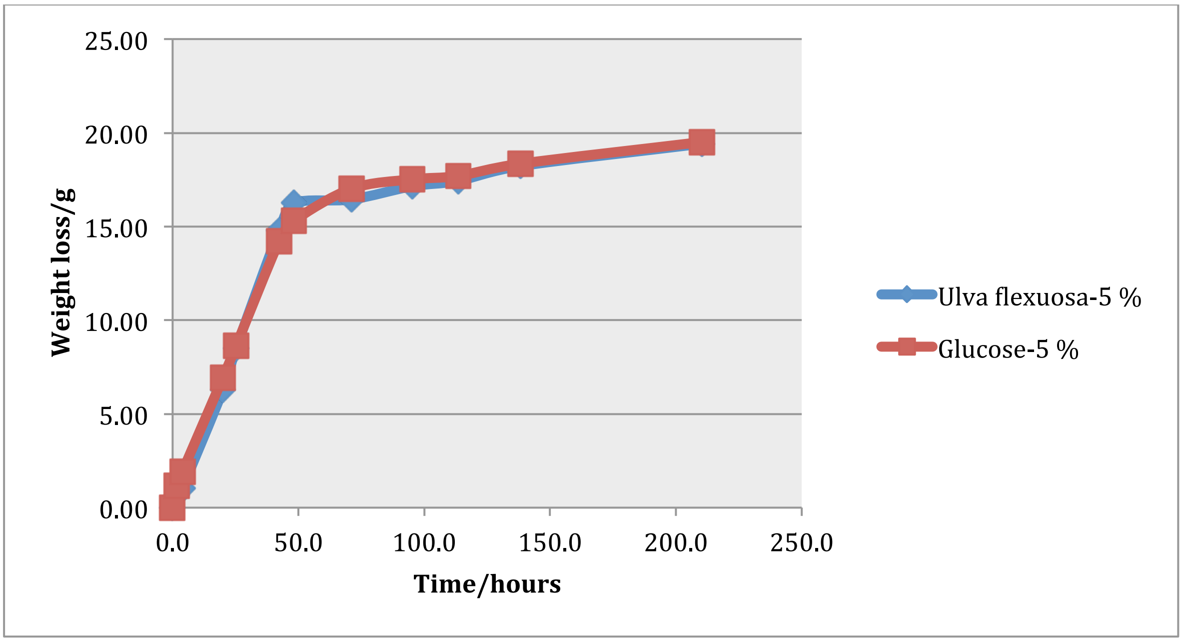

Figure 3: Comparison of weight loss in *Ulva flexusosa* hydrolysate (spiked with 5 % glucose) with 5 % glucoseat 32 °C in 20 ml fermentation flask after 100 hrs.

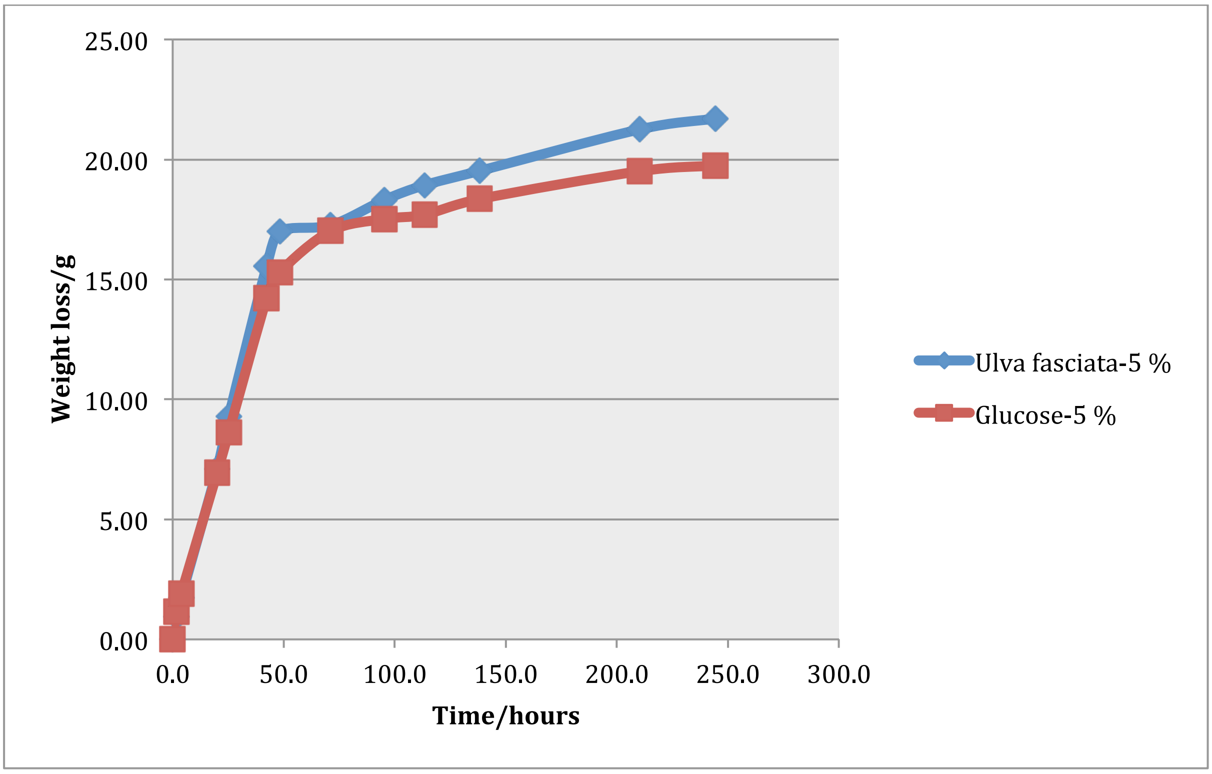

Figure 4: Comparison of weight loss in *Ulva fasciata* hydrolysate (spiked with 5 % glucose) with 5 % glucoseat 32 °C in 20 ml fermentation flask after 1 week.

The weight loss for the hydrolysate spiked with 5 % glucose was very comparable to the 5 % glucose only as shown in **Figure 3** and **4** and **Table 8.** After 1 week of fermentation, the highest weight loss (21.7±0.4 g/L) was observed in *U. fasciata*. This was higher than weight loss for 5 % glucose only

(19.8±0.8 g/L). There was no difference in weight loss for 5 % glucose only (19.8±0.8 g/L) and weight loss for 5 % *U. flexuosa* hydrolysate (19.8±0.3 g/L) as shown in **Table 8. The** ethanol generated as a result of weight loss was comparable to the theoretical ethanol. The higher fermentation efficiency at 1 % glucose concentration level was seen in *U. flexuosa* (51.4%) after 24 hrs., but this was lower than glucose only. At 5 %, *U. fasciata* showed the highest fermentation efficiency (88.5 %), even higher than pure glucose after 1 week.

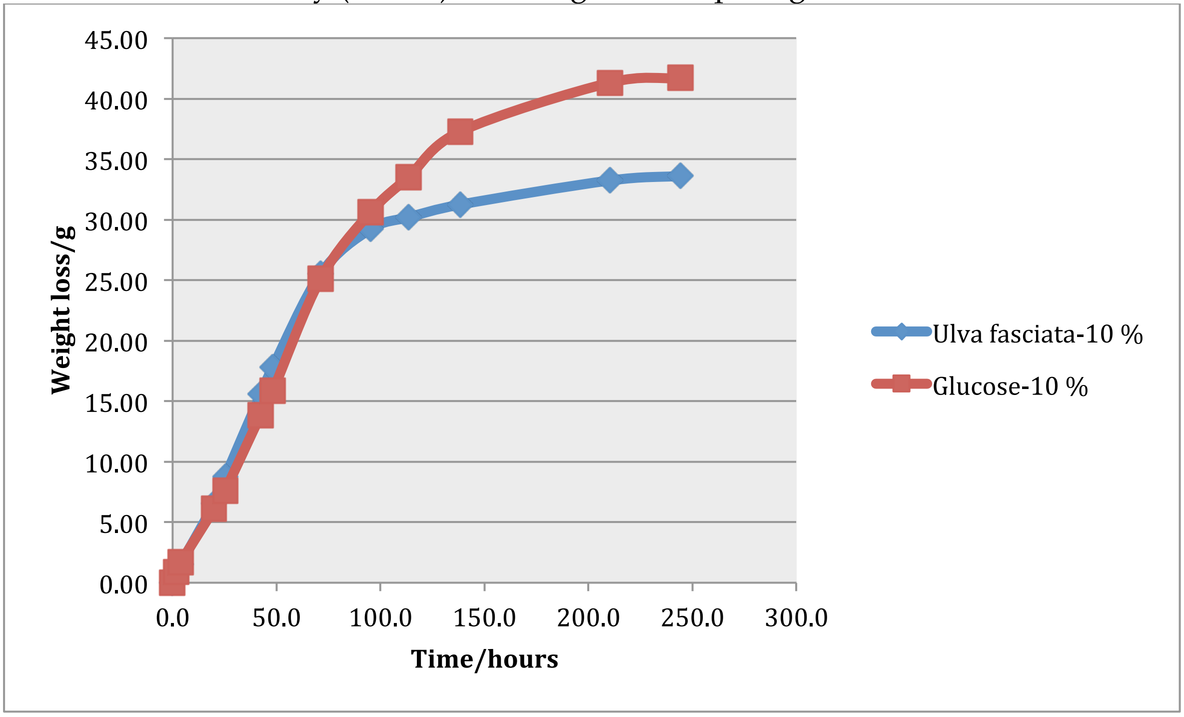

Figure 5: Comparison of weight loss in *Ulva fasciata* hydrolysate (spiked with 5 % glucose) with 10 % glucose at 32 °C in 20 ml fermentation flask after 1 week.

The weight loss for the hydrolysate spiked with 10 % glucose was very comparable to the 10 % glucose only as shown in **Figure 5**, **6** and **Table 8.** After 1 week of fermentation, the highest weight loss (43.4±0.3 g/L) was observed in *U. flexuosa.* This was higher than weight loss for 10 % glucose only (41.7±8.1 g/L). There was a mark difference in weight loss for 10 % glucose only (41.7±8.1 g/L) and weight loss for 10 % *U. flexuosa* hydrolysate (33.6±1.0 g/L) as shown in **Table 8. The** ethanol generated as a result of weight loss was comparable to the theoretical ethanol. The higher fermentation efficiency between the 2 *Ulva sp.*at 1 % glucose concentration level was seen in *U. flexuosa* (51.4%) after 24 h, but this was lower than glucose only (61.5 %). At 10 %, *U. fasciata* showed the highest fermentation efficiency (88.5 %), even higher than pure glucose after 1 week.

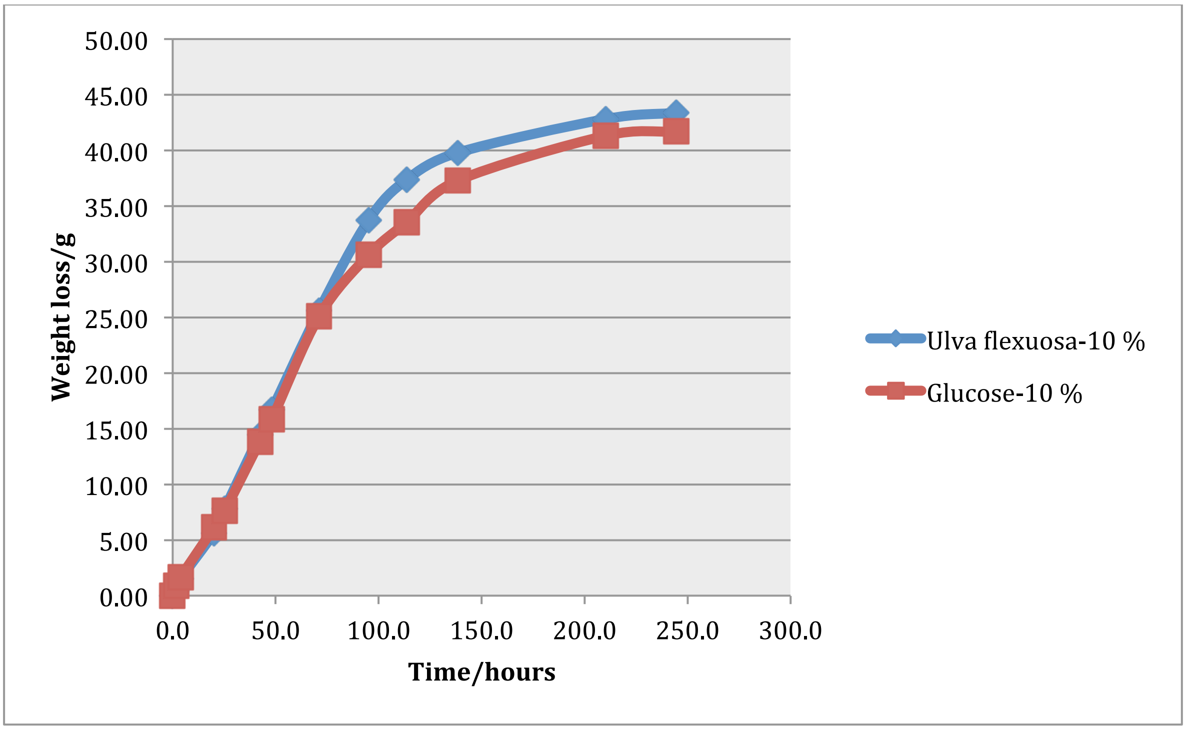

Figure 6: Comparison of weight loss in *Ulva flexuosa* hydrolysate with 10 % glucose at 32 °C in 20 ml flask after 1 week of fermentation.

Table 8: Weight loss, Potential ethanol yield and fermentation efficiencies of *U. fasciata and U. flexuosa* using Baker's yeast strain incubated at 32 °C, pH 4.8 for 24 h at 1 % level, 100 h at 5 % level and 150 h at 10 % glucose concentration

Sample	Glucose spike	Glucose Hydrolysate	Glucose Concentration	Theoretical Ethanol	MaximumWeight Loss	Ethanol yield	Fermentation Efficiency	Final pH
	%	(g)	g/L	g/L	g/L	g/L	%	
Glucose	1 %	0.000	10.00	5.1	3.0±1.4	3.1±1.5	61.5	4.4
Glucose	5 %	0.000	50.00	25.6	19.8±0.8	20.7±0.8	80.8	4.1
Glucose	10 %	0.000	100.00	51.1	41.7±8.1	43.6±8.5	85.3	4.0
U. fasciata	1 %	0.003	10.15	5.2	2.3±0.1	2.4±0.2	46.0	3.9
U. fasciata	5 %	0.003	50.15	25.6	21.7±0.4	22.7±0.4	88.5	3.7
U. fasciata	10 %	0.003	100.15	51.2	33.6±1.0	35.1±1.1	68.7	3.6
U. flexuosa	1 %	0.004	10.18	5.2	2.6±0.2	2.7±0.2	51.4	4.3
U. flexuosa	5 %	0.004	50.18	25.6	19.8±0.3	20.7±0.4	80.7	3.7
U. flexuosa	10 %	0.004	100.18	51.2	43.4±0.3	45.4±0.3	88.6	3.8

NB: Values are means ± standard deviations of duplicate determinations

Discussion

The green seaweeds (*Ulvas: U. fasciata and U. flexuosa*) were investigated for their total solids/dry matter, moisture content, ash content, hydrolytic potential and fermentation into bioethanol. The chemical composition of these seaweeds species from Ghana are shown in **Table 2.** Not much has been reported of the moisture content of *U. flexuosa* but the moisture content of *U. fasciata* (7.27 ± 0.26%) is low compare to 12.6 % as was reported by Siddhanta et al. (2001). The ash content of *U. fasciata* (13.18 ± 0.86) by the findings of this research is consistent with the findings (13.9 %) of Siddhanta et al (2001) and 12.79 % by Carvalho et al., (2009) but was different from Pádua, M. et al (2004) who had 20.61 % ash in December 1995 and 17.75 % ash in February 1996 for *U. fasciata*. Masutani and Yoza, (2011) however observed that the composition of seaweeds within the same species could show wide variations in their chemical composition and attributed this to environmental factors such as water temperature, nutrient availability and sunlight prevailing in the seaweeds environment.

Glucose of 40.17±2.33 % was generated in *U. flexuosa* by spectroscopic methods and this value was higher than recorded for *U. fasciata* (34.43±0.63) % under the same conditions in this research. The percent glucose from both *U. fasciata* and *U. flexuosa* increased with time of hydrolysis (Table 3). Except for under 40 minutes of autoclave time where the percent glucose in *U. fasciata* was higher (50.40±1.48) % than *U. flexuosa* (44.12±3.97) %, the percent glucose in *U. flexuosa* biomass was higher (Table 3). The percent glucose by SA hydrolysis for the different autoclave conditions were verified by the HPLC analysis (Table 4) and this was on the average three times lower than what was obtained by UV spectroscopy That is, if UV = w and HPLC = y, then w = 3y is the relation between glucose obtained by UV spectroscopy and glucose obtained by HPLC. The respective percent glucose rose from 8.68±0.02 % through 12.20±0.03 to 32.43±0.03 and 13.46±0.03 % through 14.33±0.05 to 22.96±0.10 for *U. fasciata and U. flexuosa.* The higher glucose from the UV spectrophotometry analysis could be attributed to the excess delocalized protons (H^+) in solution (see equation 2 of the D-glucose-HK assay procedure). The NADP+ could still attract excess free mobile H+ either than those protons (H+) from glucose, and could give higher absorbance leading to a higher percent glucose. However, at higher concentrations, SA was strong enough to hydrolyze cellulose at room temperature (Camacho et al 1996) leading to the formation of water-soluble oligosaccharides (Obolenskaya et al., 1991). The percent glucose for *U. fasciata* at 60 minutes autoclave time (32.43±0.03) %, is higher than what was recorded (16 %) by Siddhanta et al.(2001) when cold water was used to extract soluble polysaccharides and the glucose content was determined. However, 16 % was higher than the percent glucose after 20 (8.68±0.02%) and 40 minutes (12.20±0.039%) autoclave condition by the current study.

TFAH after 2 hrs. of hydrolysis with 2 M TFA concentration in 5 ml and with the same biomass concentration (3.445 g/L) as was in the SAH, showed lower percent glucose. The higher percent glucose was found *U. flexuosa* (17.36±2.67) with 13.48±1.09 measured in *U. fasciata*. On the contrary, the higher (1.80±0.01%) percent glucose was in *U. fasciata* and only 0.90±0.00 % glucose was found in *U. flexuosa* by HPLC validation. TFAH from the current study is not a better method for seaweed hydrolysis. It may be possible to hydrolyze green seaweeds using TFA at higher concentrations since the cellulose in seaweeds may be very recalcitrant to low concentration TFA attack. TFA has been used successfully to hydrolyze grape and apple skins to produce 9.5 % (94.89 µg/mg) and 9.5 % (95.07 µg/mg) glucose respectively by HPAEC-PAD analysis of the hydrolysate, which is higher than 1.8±0.01 % glucose by the same HPAEC-PAD analysis of TFA hydrolysate in the current study. TFAH in general, produced very low quantities of glucose from green seaweeds and may not be the ideal method for hydrolysis of chlorophyta.

Enzymatic hydrolysis using the novel enzyme complex cellulases (Cellic Ctec2) was used at pH 5, 50 °C for 1 hr., 4 hrs. and 24 hrs. for the hydrolysis of seaweed biomass and this is presented in **Table 5, 6 and 7**. The amount of percent glucose from enzymatic hydrolysis after 1 h was higher in *U. flexuosa* in all the different enzyme-substrate concentration than *U. fasciata* for the same conditions of treatment (**Table 5)**, although there was no significant difference between them. One would have thought there were inhibitions affecting the enzyme activity. Thus, pure cellulose was treated with the cellulose complex and relatively low percent glucose values were detected by UV spectroscopy though it was significantly different ($P \leq 0.05$) from what was measured for the seaweeds.

When the time for the enzymatic hydrolysis was increased to 4 h while maintaining the temperature and pH conditions in a 50 mM sodium acetate buffer at 1, 6 and 10 % enzyme-substrate concentration, the percent glucose at 1 % increased from 1.82±1.07 % to 3.91±2.20 % in *U. fasciata* and 2.19±0.70 % to 3.25±3.92 % in *U. flexuosa*. There was also a marginal increase in percent glucose from cellulose – 11.70±3.38 % to 20.08±2.09 % after 4 h of hydrolysis for 1 % enzyme-substrate concentration (**Table 5 and 6)**. At 6 % enzyeme-substrate concentration, the amount of glucose in the supernatant for the *Ulvas* and cellulose, after 4 h of hydrolysis, were lower than 10 % (**Table 6)**. The percent glucose in 10 % E/S concentration after 4 h was remarkably lower in both seaweed species but had increased by 3.5 % in cellulose (**Table 6).**

The cellulose complex did not seem to be effective after 4 h. The reaction was repeated for 24 h at the same conditions of pH 5, 50 °C at 1, 6 and 10 % E/S concentration and the percent glucose was monitored by UV spectroscopy (**Table 7).** Thepercent glucose was lower than 10 % for both *U. fasciata and U. flexuosa* (33.6 5 % glucose was the highest converted from cellulose after 24 h of hydrolysis). The amount of glucose from the *Ulva fasciata and U. flexuosa* by enzymatic hydrolysis after 24 h and 6 % E/S concentration (6.59±1.06 and 8.89±0.52) was comparable to the HPLC validated values (8.68±0.02 and 13.46±0.03) respectively after 20 minutes autoclave time during SAH (**Table 4 and 7**). This suggests that the quality of determination of glucose by UV spectroscopy matched with that of the HPLC analysis. Otherwise the percent glucose from enzymatic hydrolysis by UV spectroscopy is nowhere comparable to the percent glucose from SAH by UV spectroscopy. The percent glucose from enzymatic hydrolysis was not validated by the HPLC methods since the amount of glucose measured in the substrate by UV spectrophotomer was generally lower. Unlike the acid hydrolysis where excess hydrogen ions in solution could give a false count of absorbance leading to higher glucose measurement, the percent glucose measured in the case of the enzymatic hydrolysis may be reflecting the true activity of the cellulose complex Cellic Ctec2. However, the performance of the cellulose complex on cellulose where only 33 % glucose was obtained remains a huge question to answer. Research shows that the degradation efficiency of the enzyme *Cellic Ctec2* depends on the initial physical quality of seaweeds (Salar et al., 2012). When seaweed biomass was pretreated with *Cellic® CTec2* in order to hydrolyze it to get higher organic content for methane production, comparatively low methane potential was shown (Salar et al., 2012). The enzymology of *luminaria digitata* using alginate lyase and *Cellic Ctec2* cellulase enzyme in combination has also been reported. When a mixture of alginate lyase and a cellulose preparation (Cellic®CTec2) were used on large-sized milled material of *Laminaria digitata* all the available glucose were released within 8 h (Dirk et al., 2015). On the contrary, when the cellulase preparation alone (*Cellic Ctec2)* was used only half of the available glucose was released. Masutani and Yoza (2011) during ethanol production from *U. fasciata* used the commercial cellulose *Accelerase* from Genencor and recovered 25 % glucose after 12 h digestion. The use of this cellulase complex, *Cellic Ctec2,* for the hydrolysis of green seaweeds at the specified enzyme substrate concentrations is still in the dark and thus, further research is needed to unravel the mystery.

Both *Ulva fasciata and U. flexuosa* have shown high total dry matter (Table 2) which has resulted in the release of approximately 12% and 14 % glucose respectively by HPLC analysis (**Table 4**) during SAH and autoclave time of 40 minutes. These hydrolysates whose glucose concentrations were known were spiked with 1 %, 5 % and 10 % glucose concentrations in 20 ml volume of a 50 ml fermentation flask, the pH adjusted to 4.8, and used for fermentation of ethanol. Experimental controls comprising of glucose only in these specific concentrations (1, 5 and 10%) were fermented simultaneously and monitored as shown in **Figures 1-6 and Table 8.** *U. flexuosa* which originally showed a higher glucose concentration from the HPLC analysis exhibited this in the yield (Table 8 and Figure 6) following the stoichiometry reaction where 2 moles of ethanol is produced from 1 mole of glucose by *Yeast.* Approximately 89 % fermentation efficiency was achieved with *U. flexuosa* at 10 % glucose concentration. This was much higher than the fermentation efficiency for *U. fasciata* and glucose only which was expected due to the excess glucose expected in the hydrolysate even though this trend was not seen at 5 % added glucose level when equal efficiencies were achieved for both ethanol and *U. flexuosa*. This was not so for *U. fasciata* which showed lower ethanol yield (Table 11) and lower conversion potential (approx. 69 %), although it exhibited approximately 89 % fermentation efficiency at 5 % added glucose concentration level. Obviously, the observations reported during the fermentation process in this study are quiet promising. The bottle neck is how to ensure a mild and easy simultaneous saccharificationa and fermentation of the green seaweeds to maximize production of ethanol.

Conclusion and recommendation

The results of this study show that *Ulva fasciatata* and *Ulva flexuosa* have the potential of glucose been extracted from them for the eventual production of ethanol. However, further research is needed to identify the hydrolytic treatment of the biomass for higher glucose yields.

Acknowledgement

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SCALING UP GAS CABINET DRYING OF MANGOES IN THE YILO KROBO DISTRICT OF THE EASTERN REGION IN GHANA: NEEDS ASSESSMENT OF MANGO FARMERS

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Abstract

Mangoes are widely cultivated in many parts of the world. The Yilo Krobo District of the Eastern region in Ghana is a major hub for mango production. However, mango farmers in this area encounter losses of revenue through unfair market pricing, fruit spoilage and lack of value addition to fresh mangoes. The lack of value addition is the result of dearth in knowledge and skills for processing fresh mangoes into various food forms such as dried mangoes. The need to train mango farmers and equip them with knowledge, skill and capacity to process fresh mangoes into value added mangoes products was therefore proposed. In order to implement this intervention, a needs assessment of mango farmers, with a focus on mango processing was done by a survey of 54 farmers, directly contacted in the Yilo Krobo District. Captured information of respondents included their demography, farming and processing activities. The questionnaire also included a section for collecting information on farmers needs in the area of mango processing. Data obtained were analyzed using descriptive statistics. Interestingly, 74.1% were male and 25.9% were female respondents. The mango farms were individually owned (55.6%), group owned (27.8%), family owned (11.1%) or a partnership (5.6%). Only 8% respondents exported their fresh mangoes, while the remaining sold to the local market. Direct sales of fresh mangoes to market women was 52.2% compared to 47.8% purchased by fruit processing companies in Ghana. Mango processing activities in the district was limited as none of the respondents was involved in any form of mango processing. However, all respondent showed interest in adding value to their fresh mangoes through processing, especially dried mangoes. All respondents agreed that this could help reduce postharvest loss of mangoes and increase their incomes. Generally, all respondents were experienced and knowledgeable in mango farming and agreed that they needed training, especially in the area of fruit handling and processing into value added mango products. Based on the findings, a training and capacity development on Gas Cabinet Drying technology for drying mango was recommended for farmers in the Yilo Krobo District.

Keywords: *Mango, Mangifera indica, Processing, Survey, , Gas Cabinet Drying*

1.0 Introduction

Mango (*Mangifera indica* L.) is among the most widely cultivated and consumed fruits in tropical and subtropical regions of the world. It is commonly known as king of fruits because of its strong aroma, delicious taste and high nutritive value. According to Jedele *et al.* (2003), mango contributes to about 50% of all tropical fruits produced in the world. India is the world's largest producer (12, 342,890.52T), followed by China, Thailand, Mexico, Indonesia (FAOSTAT, 2013). In Africa, Nigeria is the leading producer (850,000T), followed by Egypt (FAOSTAT, 2013). In Ghana, mangoes are popular fruits during the last quarter of every year. Its production in Ghana increased from 80,000T in 2010 to 95,460 in 2013 (FAOSTAT, 2013), making the commodity very prospective in terms of foreign exchange earnings. However, this increase in production is affected by scale insects, mealy bugs and stone fruits (Odzeyem, 1998). Interestingly, the mango anthracnose is the most important disease affecting mango production and marketing worldwide (Jeffries *et al.*, 1990; Crane and Campbell, 1991; Nelson, 2008; Fitzell, 1981; Ilag, 1992). The disease affects the leaves, twigs, petioles, panicles and fruits of mango (Nelson, 2008).

Although, the fruits are largely sold on the local market, a significant proportion of the produce is exported to the European Union and some parts of the Middle East. Several kinds, including local and exotic varieties including Kent, Keitt, Erwin, Palmer, Springfield and Tommy Atkins are grown for different purposes and markets. Currently, mango production in Ghana has developed since scientific methods and various good agronomic practices were introduced in the sector. These interventions have translated into increased production margins over the past 10 years. Although, mangoes are abundant during the glut session, huge quantities are loss through postharvest handling. Therefore, improving the mango value chain in Ghana is important to the sustainability of the sector. Successful postharvest handling of mangoes requires knowledge of the postharvest physiology of the fruit and understanding how this affect handling practices to maintain and develop high quality fruit (Yahia, 2005; Brecht and Yahia, 2009; Yahia *et al.*, 2006). The postharvest handling system used for mangoes also depends on the marketing system in which the fruit will be sold. This includes factors such as distance to the market, the desires and expectations of the consumers in that market, and the availability of labour, technology and infrastructure required for various handling options.

Successful postharvest handling of mangoes involves managing the ripening process and avoiding quality losses due to physical damage and decay (Dupriez and de Leener, 1998; Epstein, 1998; Nakasone and Paull, 1998; Subhadrabandhu and Othman, 1995). Currently, most mango growers produce and sell mangoes in its raw form to both local and export markets. This limits the opportunities and economic returns on their harvest. In seasons of glut, losses of more than 20% are encountered. This issue prevails because of a lack of technical skills by farmers and small scale processors, and infrastructure for processing surplus into value added products.

Subsequently, processing mangoes into forms such as dried chunks and chips would contribute to increasing returns and reduction of losses (Brecht and Yahia, 2009). Drying of mangoes presents an opportunity for value addition to the crop and ensuring an almost all year round supply of the fruit. Dried fruits are becoming popular in the Ghanaian food system. They are convenient and retain most of the nutrients of fresh fruits and are therefore considered healthy and increases the economic prospects for farmers and processors who engage in mango drying.

In an attempt to build capacity and enhance the technical ability, many training programs have been developed for mango farmers in the Yilo Krobo District (USAID-West Africa Trade and Investment Hub, 2016; EDAIF, 2014; FAGE, 2013). Interestingly, these trainings have been successfully as mango farmers have increased their production from 80,000T (2010) to 95,460 (2013) according to FAOSTAT (2013). However, most of these training programs were agronomy-based and did not include a food processing component, which is needed to efficiently process raw mangoes into value added forms. As a result there is a huge knowledge and skill dearth, in regards to fruit processing, among farmers and processors in the Yilo Krobo District. An intervention therefore was to introduce, train and equip mango farmers, producers and processors in the Yilo Krobo District, with the knowledge, skill and capacity to process dried mangoes. However, in order to implement this intervention, a needs assessment of mango farmers, with a focus on mango processing was conducted in the Yilo Krobo District of the Eastern region.

2.0 Methodology

2.1 Study area and target population

A survey on needs assessment was carried out in the Somanya and surrounding towns in Yilo Korbo District of the Greater Accra Region. The study area was one of the major mango growing hubs in Ghana, producing more than 4,000MT annually. In this assessment, 54 mango farmers were surveyed.

2.2 Data collection

A questionnaire was used as the data collection instrument (Appendix 1 and 2). The questionnaire was sectioned into different elements in order to collect demographic data, information on farming and processing activities, training needs and these served as the basis for the assessment. The questionnaire generally contained close-ended questions. However, in order to elicit elaborate responses from respondents, open-ended questions were included.

2.4 Data analysis

Responses from the survey were coded and entered into SPSS (version 17.0.1) and analyzed using descriptive statistics.

2.0 Results and Discussions

3.1 Socio-demographic characteristics of mango farmers

The respondents of the survey were either mango farmers or mango primary processors. The demographic characteristics revealed that three-quarter of respondents were males (74.1%) while the rest were females (25.9%) (Table 1). Nearly, 70% of the respondents were more than 40 years, an indication that youth involvement in mango farming in the study area was limited. Respondents less than 30 years was 7.4%. The respondents were generally educated, with more than half of them having attained at least secondary school education. Approximately, 7% of respondents had no formal education. Most of them were household heads who were managing an average household of 5 to 9 members. In a similar study conducted in Rwanda in ten districts involving 77 farmers, 73% of respondents were household heads and 48% interviewed attended primary education whereas 32% never had any formal education (Kagiraneza *et al.*, 2014). In addition to farming and processing, some of the respondents were engaged in minor occupations such as food stuffs trading and sewing.

Table 1: Demographic characteristics of respondents

Variable	Frequency	Percentage (%)
Age		
<=30	4	7.4
31-40	13	24.1
41-50	10	18.5
>=51	27	50.0
Educational level		
No education	4	7.4
Primary	11	20.4
Secondary	22	40.7
Tertiary	14	25.9
Other	3	5.6
Occupation		
Farmer	48	88.9
Processor	2	3.7
Other	4	7.4
Household headship		
Head	44	81.5
Not head	10	18.5
Size of Household		
0-4	17	31.5
5-9	30	55.6
>=10	7	13.0
TOTAL	**54**	**100.0**

3.2 Company information

Most (53.4%) of the farmers had been involved in mango production for more than 11 years. Ten percent (10%) of respondents had farmed for less than 5 years, while the remaining 36.7% had been involved in mango production for the past 5-10 years. Although formal business registration is important and presents advantages such as easy access to loans and other financial services, surprisingly, only 17% of the farmers had formally registered their farms as business entities. The remaining 83% operated farms, which were not registered as formal businesses. None of the processors had formally registered their engagements as companies. Farm sizes ranged from 1 to 50 acres and 45% had less than 5 acre farms, 32.5% had 5-10 acre farms and the remaining 22.5% had farms which were bigger than 10 acres. The respondents disclosed that they employed an average of 5 people (mostly men) as permanent staff on the farms. However, during harvesting, an average of 9 casual workers were employed, and these workers were paid wages as casual labourers. This underscores the fact that mango production is a big business in the Yilo Krobo District. The respondents reported that the farms were individually owned (55.6%), group owned (27.8%), family owned (11.1%) or a partnership (5.6%).

3.3 Farming activities

Mangoes grown in the Yilo Krobo District included local variety and exotic varieties such as Keitt, Kent, Haden, Erwin, Palmer and Springfield. These exotic varieties were grown for both the international and local markets (Figure 1).

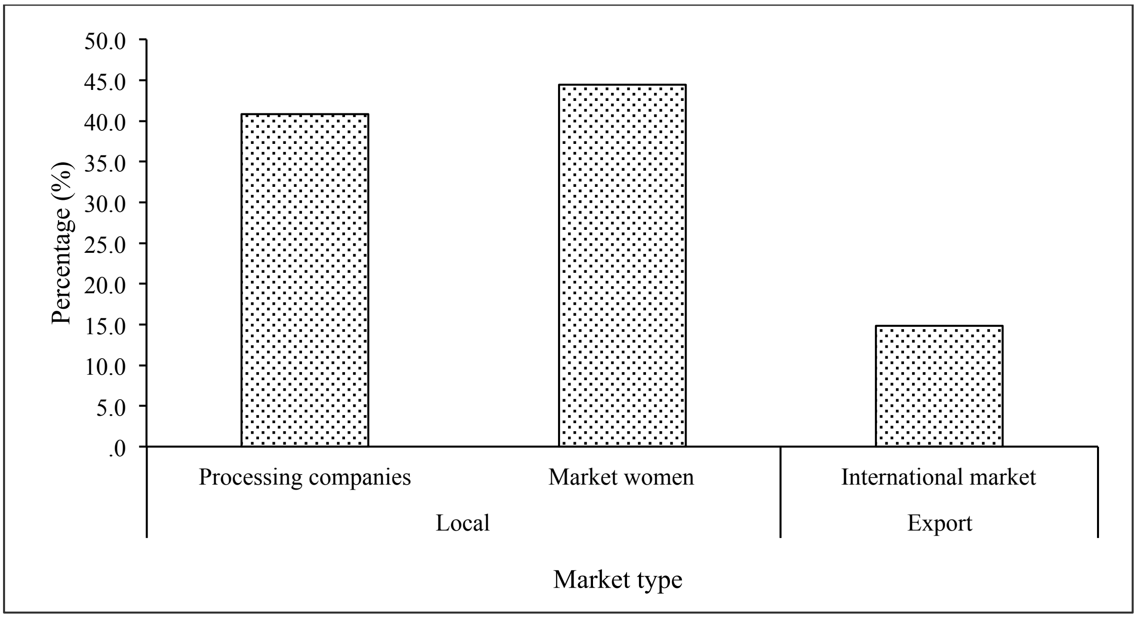

Figure 1: Market for mangoes grown in Yilo Krobo

Only 8% of the respondents exported their produce, while the remaining were sold to local markets. A bulk (52.2%) of the mangoes sold locally were sold directly to market women, while the remaining (47.8%) were purchased by local fruit processing companies. About (33%) of the mango farmers practice manual farming system (Table 2). This farming system does not involve the use of machines and other mechanized implements and was prone to intense human labour and drudgery. The remaining 66.7% adopt combination of these two farming systems. However, the level of mechanization in this scheme was basic and limited to the use of tractors/plough for land preparation and mechanized sprayer for application of fertilizer, weedicide or insecticide.

Table 2: Farming systems and other crops produced

	Response*	
	Yes	No
Farming system		
Manual	18 (33.3%)	-
Mechanized	0 (0%)	-
Combined	36 (66.7%)	-
Mechanized equipment		
Use of tractor/plough	37 (68.5%)	17(31.5%)
Knapsack sprayer	45 (83.3%)	9 (16.7%)
Other crops grown		
Maize	24 (44.4%)	30 (55.6%)
Cassava	8 (14.8%)	46 (85.2)
Vegetables (okro and pepper)	11 (20.4%)	43 (79.6%)

*Responses are presented as frequency and percentage (in parenthesis)

Apart from mangoes, some of the farmers also planted other crops such as maize (44.4%), cassava (14.8%), okra and pepper (20.4%) (Table 2), which was similar to respondents surveyed in Rwanda, who planted apart from mango, mainly citrus (46.8% of respondents) and Avocado (36.3%). Other fruit crops grown in surveyed areas were guava, pawpaw, tamarillo and banana (Kagiraneza *et al.,* 2014).

Respondents hired both males and females on their plantation. The males were usually involved in weeding, application of chemical whereas the females were involved in pruning and harvesting. Both males and females were involved in carrying the fruits from the point of harvest to collection points before haulage from the farms.

In order to preserve quality through proper fruit handling, farmers revealed that harvesting of mangoes was done manually by plucking the mangoes from trees directly into crates or baskets (Figure 2), similar to the harvesting of mangoes reported in other studies (Crane and Campbell, 1991; Nelson, 2008; Ilag, 1992). A small section of respondents also lined the ground with polythene sheets and plucked the mangoes on them. According to the farmers, after harvest, the fruits were hauled by light trucks or mopeds to market centers, processing facilities or pack houses, where they were prepared for export. However, diseased fruits was a major challenge of respondents, which was noted in earlier studies (Kagiraneza *et al.,* 2014; Kazmi *et al*., 2005; Khalid *et al*., 2002; RHODA, 2008; Saeed *et al*., 2007).

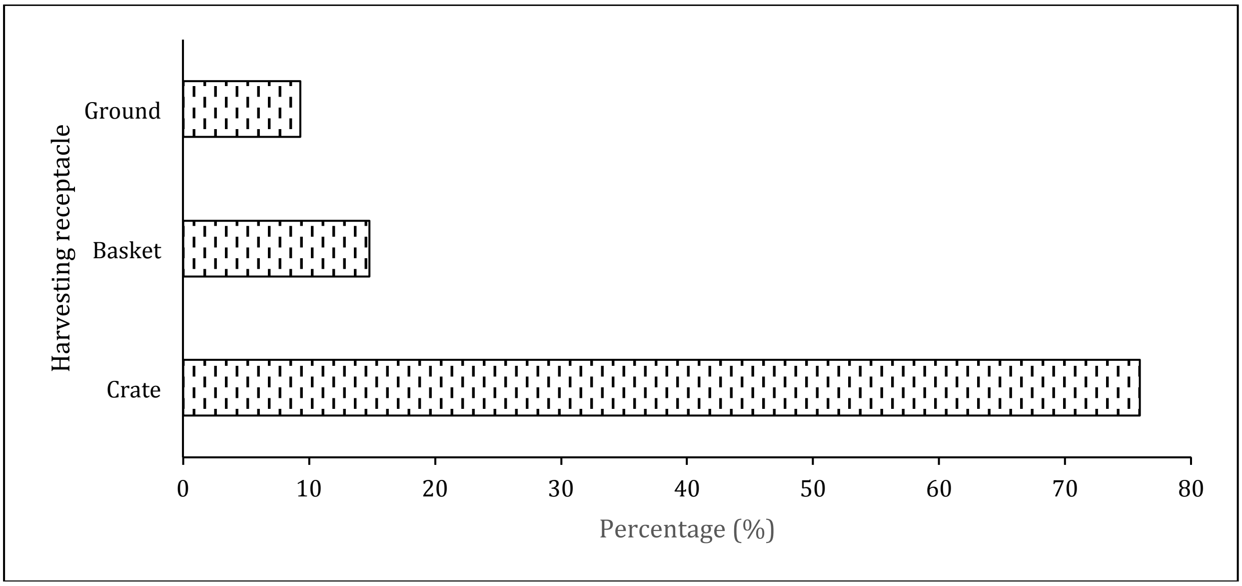

Figure 2: Harvesting receptacles used by respondents

3.4 Processing activities

Mango processing activities in the district was not as popular as mango production. None of the mango farmers were involved in any form of mango processing, even though they showed interest in adding value to their raw produce through processing. The farmers conceded that this could help reduce postharvest losses of mangoes and therefore increase their income. Similar agreement was reported by Jedele *et al*. (2003).

3.5 Training and capacity building

Nearly, 54% of the respondents revealed that they had not received any training or capacity building for farmers on postharvest management and fruit processing. The remaining 46% had attended training on postharvest management organized by governmental and non-governmental agencies. According to the respondents, MOFA, USAID, GIZ and processing companies such as HPW and Blue Skies occasionally organize training and capacity-building workshops for them. Some topics discussed in previous training workshops, as articulated by the respondents are listed in Table 3.

Table 3: Previous training programs

Type of Training	Organizer	Topic
Farm management	MOFA	Good Agricultural practices, pest and disease control
Pre-harvest and Post-harvest management	USAID	Production of good quality fruits, fruit handling and packaging, entrepreneurship, Global GAP
Agronomy	HPW	Pest and disease control and management, fruit handling
Post-harvest management	Blue Skies	Fruit handling, farm sanitation
Pest and disease control	YKMFA	Chemical application and farm sanitation

Some training topics were presented for the respondents to rate, based on 3 levels of importance i.e. "very necessary", "necessary" and "not necessary"). The outcome of this rating was presented in Figure 3. Mango drying technology was rated as the most important component of the training program, followed by marketing. Training on packaging received the lowest rating among the topics presented. Other topics suggested by the respondents for consideration in the training program include "prevention of spoilage" and "negotiation skills". All the respondents expressed their readiness to take part in post-harvest and mango processing training, since this would endow them with the technical skills to add more value to their raw produce. They were of the view that such a training would also enable them process raw mangoes into more stable forms and make the fruit available all year round. This would open up business opportunities to them and eventually enhance their livelihood.

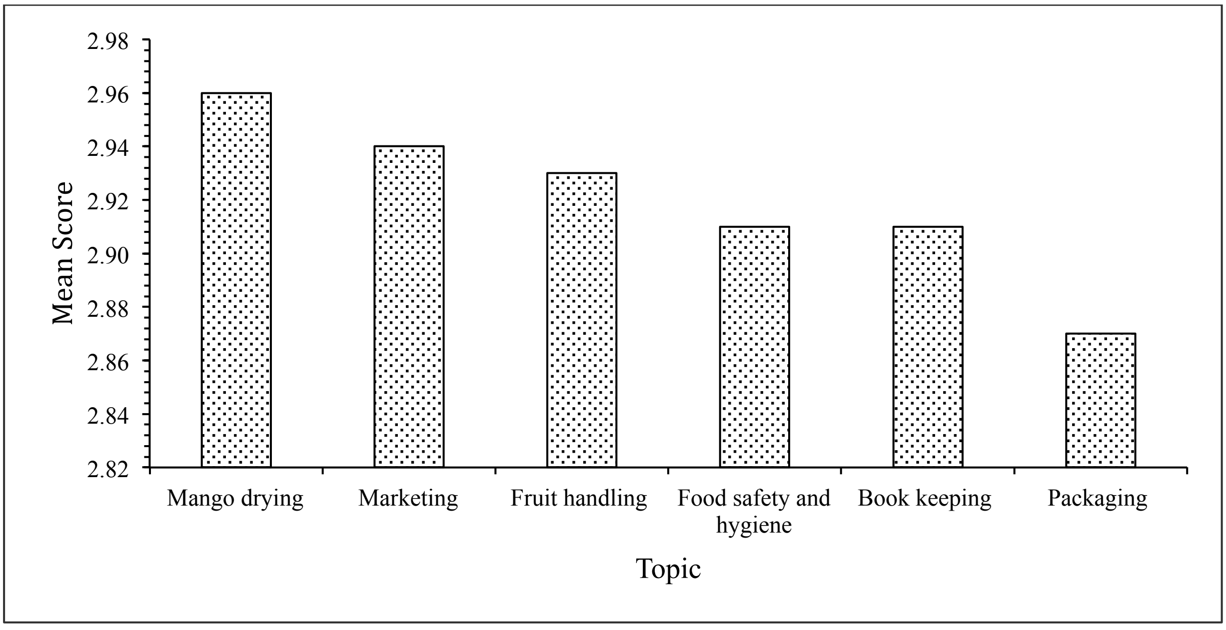

Figure 3: Ranking of training topics

Generally, even though the respondents had a lot of experience in production, their knowledge about fruit processing was limited. They readily welcomed the idea of issues that will help enhance their productivity and efficiency. Many of the respondents bemoaned the difficulty in selling their produces, especially in season of glut, which resulted in high postharvest losses and losses of revenue. Respondents complained about unfair market prices in both major and minor seasons, which makes it difficult for them to recoup their capital and or service loans they acquired.

5.0 Conclusions

The assessment showed that mango farmers and processors in the Yilo Korbo District have not had any training or capacity building program targeted at processing raw mangoes into value added forms. Training programs organized for them by governmental and non-governmental agencies were agronomy-based. In the face of high losses of revenue through poor market prices and high rate of fruit spoilage, farmers agreed, unanimously, that they needed training in fruit processing, especially the drying of mangoes. This would help them add more value to the raw mangoes by processing into dried forms. They revealed that key areas in which training will be required included fruit processing and marketing. The respondents were optimistic that such an intervention would contribute to reducing the losses they incur in mango production. As a policy direction, emphasis should be placed on encouraging women and the youth into mango production and processing. The Districts Assemblies should be mandated to assist women and the youth financially and in physical infrastructure such as the construction of the gas cabinet dryer for dried mangoes.

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MANAGING MOISTURE IN CEREALS AND GRAIN TO REDUCE POST HARVEST LOSSES

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Abstract

Moisture content in grain is critical from harvest, through storage to final sale and consumption. Very high moisture content has the risk of excessive heat due to mould growth, micro toxin contamination and sprouting (quality reduction) or even total loss of crops. On the other hand, excessive drying promotes cracking and can lead to weight loss. These conditions, if not well managed, can lead to post harvest losses (PHL) and related input loss. Around the world, testing moisture content provides a robust way to assess PHL and the suitability of grains for storage. For that reason, there are moisture meters (Cup or Probe) available for farm use for determining moisture content. These meters use whole grain samples for the test. They are calibrated against the oven test, international standard ISO 6540.

This paper is aimed at presenting the challenges confronting farmers managing moisture during harvest to final sale. It seeks to suggest alternate methods to the traditional ways of moisture measurement. Some highlights will be made on the need to calibrate these meters using approved standard methods in order to ensure accuracy, reliability, accountability and confidence.

1.0 Introduction

In many parts of Africa, and especially in Ghana, certain crops can be produced throughout the year. Major food crops such as cereals are normally seasonal crops. Consequently, the food produced in one harvest period, which may last for only a few weeks, must be stored for consumption until the next harvest, and the seed also must be held for the next season's crop. Additionally, in a market that is not controlled, the price of any surplus crop tends to rise during the off-season period (Mrema, *et al.* 2011).

In order to ensure food security during the lean season, there is the need to take pragmatic measures by way of good harvest and postharvest handling practices, including a storage system that is controlled and monitored. This will involve the availability of storage facilities for farmers during harvest to final sale. The principal aim of any storage system, however, must be to maintain the crop in prime condition for as long as possible. The storage and handling methods should be such that losses are minimized, but must also be appropriate in relation to other factors, such as the economies of scale, labour cost and availability, building and machinery costs. In order to achieve these, it is imperative that the right moisture contents, depending on the type of crop, are attained before the grain enters storage. Even during storage, moisture contents are to be checked and retained until the produce is sold on the market. The best way to determine if moisture levels are safest for storage is to use calibrated moisture meters. These meters are meant to help farmers determine when to harvest, forecast pests, store and market optimally.

Unfortunately in Ghana, the use of moisture meters is not common among farmers and warehouse operators. Even the few that are available, farmers who have access do not want to use them. This is due to the fact that, there has not been much sensitization on its relevance.

It is however important to know that moisture testing reduces PHL best when it is done early in the harvest and postharvest handling process- during harvesting, drying and aggregation when representative sampling is easy. Retesting moisture after grain is in sacks, stacked in storage, or stored in bulk means additional costs to unload, sample, test and then reload.

In most Sub-Saharan African (SSA) countries, grains are harvested regardless of moisture content onto a drying platform. This method of drying grain after harvesting is the normal practice amongst most farmers in our local farming communities. However, can we be sure that the crops are dried to the appropriate moisture levels before they are stored or transported to the market?

The traditional methods of determining moisture content are still widely in use because education and awareness on the modern methods have been very low. In the subsequent discussion, we will analyse the traditional methods against the use of moisture meters.

1.1 Determination of moisture content on the farm

Table 1.Comparing the practicality of moisture meters in Sub-Saharan Africa

	Primitive	Tamper Prone	Certified Accurate	Quick App.	Sack App.	Bulk App.
Bare Hand	Yes	Very	No	Yes	No	No
Bite	Yes	Very	No	Yes	No	No
Salt	Yes	Yes	No	Tedious	No	No
PHL Meter Probe	No	No	**Yes**	Medium	**Yes**	No
Screw Top (cup)	No	No	**Yes**	**Yes**	No	No
Open Top (cup)	No	Yes	Not in Ghana	Yes	No	No
2 Prong	No	Yes	Not in Ghana	Yes	Yes	No

From the above table, it can be seen that the traditional methods of determining moisture in grain, namely Bare hand, Bite, Salt are not certifiable, even though they are used by most farmers. Neither of these methods require expensive equipment and neither is certified because they are very subjective and error prone. The use of screw top and probe meters are found to be most appropriate because they can be certified, cannot be tampered and are easy to use.

Moisture meters for farm use are calibrated to operate most accurately within a specific moisture range, typically 11-20 %, with an accuracy of ± 0.5 % (HGCA, 2008). There are, however, certain factors that need to be considered since they could cause errors during measurement. They include inadequate grinding of grain (if required), temperature differences between grain and meter/probe, poor maintenance of meter and the use of a damaged probe or measuring cell. Other factors are the depth of probe insertion into the grain, whether the grain moisture required is outside the measuring range of meter/probe and last but not the least, contaminants like soil and screenings.

1.2 Determination of Moisture Content in the Laboratory

The most accurate method of measuring grain moisture content is the Standard Oven-based method, which uses an International Organization for Standardization (ISO) specified protocol to dry a prepared sample of ground grain (other than maize) in a laboratory oven (ISO 712:1998).

The weight loss during drying is used to calculate the moisture of the sample. The moisture content is the loss in mass, expressed as a percentage, undergone by the product under the conditions specified in the standard. This procedure provides measurement accuracy of 0.15 % (HGCA, 2008).

Possible errors during measurement could be caused by unrepresentative grain sample, inadequate grinding, incorrect oven drying time and the inhomogeneity of oven temperature.

1.3 Principle of Operation of Moisture Meter and Its Calibration Procedure

The dielectric (capacitance) technology used in many grain moisture meters is based on the principle that a functional relationship exists between the moisture content of grain and its dielectric constant. As grain increases in moisture content (water), its dielectric constant increases. The rate at which the dielectric constant increases as grain moisture increases is not the same for all grain types; therefore, a unique calibration equation has been developed for each grain type to be measured. Moisture meters based on the dielectric principle typically incorporate a test cell in the form of an electrical capacitor, that is, two conductors separated by an insulator (Lee, 2006).

When a grain sample to be measured is placed between the conducting surfaces of the test cell, the grain displaces most of the air. By sensing the change in the electrical characteristics of the capacitor due to the dielectric properties of the grain sample, the meter can predict the moisture content of the sample. The best method, however, to calibrate a moisture meter is the oven-based method. This is usually done in a laboratory. The oven-based reference method is used to determine the reference moisture of grains.

The Ghana standards Authority Metrology Laboratories, being the custodian of the weights and measures and the designated National metrology Institution at the International Bureau of Weights and Measures (BIPM), has methods and procedures for calibrating moisture meters. In the calibration procedure, the sample is homogenized and made to attain the temperature of the laboratory and reference values determined. A quantity of grain sample is weighed and measured using the reference moisture meter, which is the working standard. The results are then recorded. The same sample and the customer's moisture meter are used to determine the moisture content again. The results are then compared and if there are any deviations, the customer's moisture meter is adjusted. After the calibration, the results obtained are calculated and presented on a certificate conforming to the requirements of ISO 17025. A calibration sticker is affixed on the Equipment Under Test (EUT), after the calibration.

2.0 Methodology

The current study was based on extensive literature review and analysis of previous studies on the subject. The study synthesised information from different sources to draw conclusions on best approaches to manage grain moisture content to reduce post-harvest losses. The authors also relied on procedures or recommended practices prescribed by the Ghana Standards Authority (GSA) Metrology laboratories (Document Nos. GSA-OP-C64-A, GSA-OP-C65-A and GSA-OP-C67-A) to ensure that grain moisture content is at acceptable levels to reduce post-harvest losses. These procedures include the use of the reference oven method for determining moisture content.

The reference method for determining the moisture content used at GSA is the oven-based method. The procedure involves grinding the sample, if necessary, after pre-conditioning, when required. A test portion is then dried at a temperature of 130 °C ± 3 °C for a specified number of hours. Percentage moisture is calculated based on the amount of weight loss in the grain sample.

3.0 Results and Discussions

3.1 Challenges Confronting Farmers Managing Moisture Measurement

Most farmers in Ghana basically store their harvested produce themselves. This is done at the farm gates or at the farmers' place of residence. In so doing, quality is compromised due to inappropriate methods of determining moisture levels before storage as well as poor storage facilities. As earlier discussed, the traditional methods of determining moisture levels are primitive and cannot be certified.

3.2 Alternate Methods to the Traditional Ways of Moisture Measurement

The alternate method of moisture measurement is the use of moisture meters (screw top or probe type). These meters can be calibrated and certified accurate by the GSA. They are handy and easy to use. For proper monitoring and maintenance of moisture levels during storage, it is required that produce are stored in modern storage bins or warehouses provided by the Ghana Grains Council.

3.3 Need to Calibrate Moisture Meters using Approved Standard Methods

To ensure that moistures meters operate and measure accurately, it is required that they are calibrated. They are to be calibrated annually against standard meters to ensure consistency and reliability. Calibration is done in the metrology laboratories of GSA. After calibration, when the results of the meter are found to lie within tolerance, a calibration certificate is issued which certifies that the meter is safe for continues use.

For farmers and warehouse operators to understand and appreciate the use of moisture meters, it is necessary that the calibration and calibration certificate are explained. By so doing, they are able to interpret the results and are also able to detect if the readings of the meters deviate with time.

In the subsequent discussions, we are going to focus on what calibration means, how important it is to calibrate measurement equipment and also try to understand the calibration certificate and its features. When this concept is accepted and put into practice, it will be a sure way to avert the risk associated with low and high moisture levels.

3.3.1 What is calibration?

According to the International Vocabulary of Metrology- Basic and General Concepts and Associated Terms (VIM) , Calibration is defined as ''Operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties (of the calibrated instrument or secondary standard) and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication'' (JCGM 200:2012).

In simple terms, it is defined as a performance comparison of measurement quantity against a standard of known accuracy.

Every calibration certificate is intended to serve three main purposes. First, it ensures that readings from an instrument are consistent with other measurements. Secondly it determines the accuracy of the instrument readings and thirdly, it establishes the reliability of the instrument.

Calibration is a qualitative activity that has some benefits. It increases production yield and gives the assurance of consistency in measurement. It is fundamental to compliance with international, regulatory or industrial-sector specific standards that require measurements to be traceable to National Standards relative to SI units. It also ensures that measurements are compatible with those made elsewhere.

Results of measurements are most useful if they relate to similar measurements, perhaps made at different time, in a different place, by a different person with a different instrument. A calibration record must always include identification of specific standards used and a means of knowing the method used (and other test conditions if required).When these records are examined, it should be possible to demonstrate an unbroken chain of comparison that ends at National Metrology Laboratory or international Laboratory. This demonstrable linkage to National or international standards, with known accuracy, represents traceability.

Ultimately all measurements are used to help make decisions, and poor quality measurements result in poor quality decisions. Every measurement has an associated uncertainty. The uncertainty in a measurement is a non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurement, based on the information used (JCGM 200:2012).

In other words, it is a numerical estimation of the spread of values that could reasonably be attributed to the quantity. It is a measure of quality of measurement and provides the means to asses and minimize the risk and possibly consequences of poor decisions.

Reliability is judged primarily by the absence of any behaviour that would indicate that the instrument is or may be faulty. A calibration certificate is issued only if the instrument is found to be reliable, and will satisfy its intended purpose.

In order to make a traceable measurement three elements are required. An appropriate and recognized definition of how the quantity should be measured- Method, a calibrated measuring instrument- standards used, and a competent staff who are able to interpret the standard or procedure and use the instrument.

3.3.2 The calibration certificate

When an instrument undergoes calibration and it is found to be reliable and can satisfy its intended purpose, a calibration certificate is issued to that effect.
A calibration certificate that is issued will usually have the following features:

- The Title: The certificate establishes what document it claims to be.
- Name and address of calibration laboratory
- Name and address of customer requesting calibration
- Each page should be numbered and the total number of pages indicated
- Unambiguous identification of the instrument, including manufacturer, model/type, measuring range and serial number: With this information, the authenticity of the calibration relating to that particular instrument is established.
- Date of Calibration
- Identification of calibration method used or unambiguous description of any non-standard method used.
- Ambient conditions under which the calibration is carried out
- Measurements and derived units
- A statement of the estimated uncertainty of calibration results
- Signature and title of person(s) accepting responsibility for the certificate and its contents
- Traceability of the instruments used for calibration
- A statement that the certificate shall not be reproduced in part or full, except with the prior approval of the issuing authority.

The calibration certificate provides the user with an assurance that the instrument is reliable. This assurance is based on the calibration Laboratory's knowledge and experience on the behaviour of similar instruments, but is conditional upon reasonable care and use of the instrument.

Every measuring instrument needs to be recalibrated after it has been used for a period of time. Recalibration in normal practice is required once every twelve (12) months. However, depending on the frequency of usage of the instrument, the recalibration period could differ. Recalibration is required as soon as the user no longer has confidence in the results because he/she is unable to demonstrate that the measurements are traceable.

4.0 Conclusion and Recommendations

The paper has shed light on modern approaches to managing moisture in cereals to reduce post-harvest losses. The study highlighted the gaps in knowledge and practice of moisture management in cereals by farmers and other practitioners in the field of post-harvest management. The lack of awareness of the modern moisture management techniques and the non-utilization of the methods are serious drawbacks to curtailing PHL in Ghana which is crucial to achieving household and national food security. To this end, there is the need to encourage the use of the modern procedures of managing moisture in cereals to reduce post-harvest losses. Reducing PHL also requires the active involvement of the GSA as a facilitator to ensure compliance to the state-of-the-art procedures in managing grain moisture and this include ensuring that moisture meters are properly calibrated and inspected on a regular basis to ensure compliance.

Moisture testing in grains is critical in the grain value chain program. It assures quality and promotes competitiveness. However, in SSA the technology gab is so wide and the national standards knowledge, very low. It therefore calls for all stakeholders to collaborate effectively to bridge the gap.

In line with this effort, GSA is in collaboration with other stakeholders like Ghana Grains Council (GGC), Ministry of Food and Agriculture (MoFA), Ministry of Trade and Industry (MoTI), World Food Program (WFP), Deutsche Gesellschaft Fur International Zusammenarbeit (GIZ) Market Oriented Agricultural Program (MOAP), Green Innovation Centre (GIC), Agricultural Development and Value Chain Enhancement (ADVANCE) working for United States Agency for International Development (USAID). These local and International organizations are working together to provide standards, storage facilities and calibrated moisture meters to farmers in many farming communities across the country. Ghana Rice inter-professional Body (GRIB), and the Traditional Council, (from Local Government perspective), are also involved.

The GGC as part of its responsibilities has developed an enabling environment including warehouse certification, rules and regulations, training of users, etc., to enable it manage a warehouse receipt system efficiently. The use of the warehouse receipt allows the GGC members to deposit their grains in a GGC certified warehouse. This will enable many GGC member small holder farmers in particular to avoid selling their grains immediately after harvesting, when the supply of the commodity is usually highest and sometimes result in low pricing.

GSA, on its part, provides GGC members with testing and grading services. Under the GGC warehouse receipt system, all grains are graded in conformity with the national standards for grains established by GSA before they are stored in GGC certified warehouses.

Considering all the challenges associated with managing moisture as discussed, the following recommendations are hereby made:

- The Ministry of Food and Agriculture through its extension education unit should sensitize and train farmers on the use of recommended drying methods and moisture testing to ensure proper post-harvest management to prevent losses.
- On the other hand, some private sector organizations could be engaged to undertake the testing of moisture content. Personnel who undertake this exercise could be trained and certified by the GSA or any other appropriate institution. This will generate employment for many of the unemployed youth in the society.
- All moisture meters being used by farmers and warehouse operators must be calibrated by the GSA and certified to be accurate and reliable. These meters must be calibrated annually.
- The Government, through the GGC and other stakeholders should provide more warehouses for famers at designated locations so that farmers can easily deposit their produce.

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PERFORMANCE OF INNOVATION AMONG FIRMS IN GHANA: CHALLENGES AND OPPORTUNITIES

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Abstract

Innovation is critical to sustaining business competitiveness and improving productivity both nationally and internationally. Performance of innovation in developing countries is characterized by challenging business and governance conditions. This paper used the National Innovation System (NIS) perspective to analyze and assess the innovative performance of Ghanaian firms in view of their challenges and exploring opportunities for future development. The study relied mainly on secondary data and desk review and analysis was through descriptive statistics. The study revealed that firms within Ghana are innovative. However, low firm investments in R&D, inadequate public/government financial support to firms to undertake R&D activities and weak linkages between and among institutions in the innovation system were evident. Both internal and external factors were identified as factors hampering innovation activities within the firms in Ghana. Foreign Direct Investment (FDI) and private sector development were highlighted as prospects for innovation growth. It was recommended for Government policies to provide support and create enabling environment for firms to promote and sustain innovation activities.

Keywords: Innovation, Foreign Direct Investment, National Innovation System, Ghana

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1.0 Introduction

Innovation is critical to sustaining business competitiveness and improving productivity both locally and internationally. According to Sirelli (2000), the rationale to encourage firms to innovate is for better economic performance. This is for higher growth, more jobs and higher wages particularly in developing countries to be brought out of poverty (Crespi & Zuniga, 2011; Lee & Kang, 2007; Robson, et al., 2009). According to Arnold and Thuriaux (2000), there is an innovation when a product is successfully developed but on the other hand, a company or industry is considered to be innovative when there are substantial R&D funds. The concept of "innovation" encompasses not only technological innovation, that is the diffusion of new products and services of a technological nature into the economy, but equally it includes non-technological forms of innovation, such as organizational innovations including the introduction of new management or marketing techniques, the adoption of new supply or logistic arrangements and improved approaches to internal and external communications and positioning. Innovation activities among firms in Ghana are incremental or modification of existing products rather than developing completely new products/services (Tetteh and Essegbey, 2014).

For long the indicators for innovativeness were the expenditures on Research and Development (R&D) and the number of employees dedicated to R&D. R&D investments have been questioned as the driver for innovations and strengthening the competitive position of businesses as it is typically confined to input factors of an innovation. Based on the Frascati-manual of the Organisation for Economic Co-operation and Development (OECD), new indicators have however been developed by various researchers and by large institutions such as the OECD and the European Commission which is the Community Innovation Surveys (CIS). The CIS brings a three-stage, firm oriented dataset by distinguishing between inputs, throughput and output stage of an innovation process (Klomp, 2001). The introduction and elaboration of CIS actually indicates a fundamental transformation of innovation research from a process approach, to a systems approach and finally the CIS which is based on the concept of National Innovation Systems (NIS) (Arnold and Thuriaux, 2000).

Over time, the following have also been used as sources of innovation indicators for performance of innovation;

- Patents and patent citations
- Bibliometrics
- Innovation surveys:
- Inputs (R&D, other innovation expenditures)
- Outputs (Thus, product, process, organizational, marketing)

These factors and processes complement each other to understand the innovative capacity of firms and for policy guidance. It was common to presume that R&D expenditures would lead to additional knowledge, and the dissemination of that knowledge base would result in innovations, especially products and processes. However, according to Arnold and Thuriaux (2000), from a policy perspective, for several reasons additional insight into the innovation process is necessary. One of the reasons is to find out how to raise the effectiveness of innovation practices, be it through subsidies, enforcing collaborations, sector policies, or otherwise. According to Mohnen & Dagenais (2002), firms may have different ways of innovating. Whiles some firms rely on internal research others may emphasize research networks.

Ghana's Government recognizes the role of knowledge and innovation in transforming the economy, reducing poverty and increasing the country's competitiveness in international and regional trade. This recognition is reflected in various political and policy statements of the Government such as Vision 2020, the country's long-term framework for development prepared, by the National Development Planning Commission of Ghana, lays emphasis on the role of local entrepreneurship and technological development in the attainment of sustainable development of the country. The public sector plays a pivotal role in fostering innovation, including a wide range of policies and instruments that seek to correct market failures provide guidance to the private sector and facilitate the coordination of the efforts of different stakeholders (UNCTAD, 2012). Most studies have focused on the role of R&D activities, technology acquisition, firm size and age as determinants of innovation (Tetteh and Essegbey, 2014; Olsson, 2012; Shefer & Frenkel, 2005). However, since improved performance of innovation in developing countries is a key avenue for poverty reduction but is characterized by challenging business and governance conditions as mentioned by Goedhuys et al., 2008, taking into account factors and understanding their relation to innovation is relevant. This paper extends the above-mentioned and uses the NIS perspective to analyse and assess the innovative performance of Ghanaian firms in view of their challenges and exploring opportunities for future development.

2.0 Methodology

Desk review and secondary data collection methods were used to provide knowledge on the performance of innovation among Ghanaian firms. Secondary data was mainly obtained from the Africa Innovation Outlook II (AIO) report and Ghana's country report on the second phase of the African Science, Technology and Innovation Indicator (ASTII) survey. ASTII survey is an African initiative that aims to develop and adopt common indicators to be used as benchmark for measuring the development of Science, Technology and Innovation in African countries. Other secondary data sources used included the World Development Report by the World Bank, United Nations Educational, Scientific and Cultural Organization's (UNESCO) Institute of Statistics, United Nations Conference on Trade and Development (UNCTAD) report, United Nations Development Programme (UNDP) report and Ghana Investment Promotion Council (GIPC). The desk research also involved reviewing of literature from existing journal articles and institutional reports on the subject area. We reviewed previous innovation studies and reports relating to research on innovation activities and performance to provide in depth understanding of the indicators for performance of innovation in developing countries for adaptation in the Ghanaian context.

Through descriptive statistics and using the NIS perspective, the data obtained was analyzed to assess the innovative performance of Ghanaian firms.

3.0 Findings

3.1 Overview of Ghana's Science, Technology and Innovation (STI) system

The concept of National Innovation System (NIS) is proposed and defined as the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies (Freeman and Soete, 1997). Freeman and Soete (1997) indicated a broad framework for understanding the performance of innovation and this included dimensions such as agents of the NIS, which include knowledge institutions (universities, research institutes, technology-providing firms), firms, government bodies as well as consumers who are increasingly seen as a source of innovation. The framework encompasses the interactions and linkages between the various elements of the NIS and the flow of ideas and knowledge. The STI system of a country depicts the outcome of interactions of the NIS framework. Estimations of an overview of Ghana's STI system are shown in Table 1. Ghana's FDI as a percentage of GDP has improved from 37.0% to 37.9% from 2014 to 2015 with an improvement in total expenditure on R&D (Table 1). This improvement of expenditure on R&D is still below Africa Unions agreed 1% expenditure of GDP in R&D. Ghana's high technology export which is as a result of products manufactured from high R&D has also improved within 7years. However, technology creation, diffusion of innovation and human skills development (Technology Achievement Index) which also seemed to have improved for Ghana still keeps Ghana within the marginalized group indicating the need for better development to improve and become dynamic adopters like South Africa or China. With the existence of the 2000 National Science and Technology Policy explicitly for Science and Technology (S&T) development in Ghana, there is the need for similar policy explicitly for the development of strategies for promotion of innovation activities in Ghana. Also, the 2010 national STI Policy in Ghana could be reviewed to include effective strategies for innovation development and enhancing innovation activities.

Table 1: Summary of Ghana's STI system

INDICATOR	ESTIMATES
Foreign Direct Investment (FDI) as percentage of GDP	36.0% in 2014; 37.9% in 2015 (UNCTAD World Investment Report 2016)
Total expenditure on R&D as a percentage of GDP	0.23% in 2007; 0.38% in 2010 (UNESCO, 2010)
High technology exports as a percentage of manufactured exports	0.18% in 2006; 4.883% in 2013 (World Development Report 2013)
Technology Achievement Index (TAI)	Marginalized - 67 in 2002; 135 in 2015 (UNDP 2002, Shahab 2015)
Explicit science and technology (R&D) policy	Yes. 2000 National Science and Technology Policy
Explicit innovation policy and strategy	No
FINANCIAL SUPPORT FOR STI	
Agencies for funding R&D	Yes. Ghana Science and Technology Endowment Fund launched in 2008
National agencies for funding innovation	No

To improve the performance of innovation activities by increasing expenditure on innovation activities, it is important for firms to gain access to funding particularly government funding as majority of the innovative firms in Ghana are SMEs (Tetteh and Essegbey, 2014). SMEs unlike larger firms who relatively have better financial resources need some form of financial assistance to adequately perform innovation activities. As shown in Table 1, there is an existing agency responsible for funding R&D but no national agency exists exclusively for funding innovation in Ghana. This is an indication of inadequate government financial support to firms to undertake innovation activities. According to a report by UNCTAD (2012) on Ghana's Science, Technology and Innovation (STI) Policy review, Ghana's budget amounted to some GHS4.3bn in 2008. Just one per cent of this amount was required to be devoted to R&D. However, it was mostly devoted to economic affairs (GHS44.4 million), followed by health R&D (GHS3.9 million). South Africa, one of the few sub-Saharan economies with middle-income status, currently spends 0.6 percent of its budget on R&D. According to the review, business sector funding of R&D in South Africa is substantial and they were on target to achieving 1 per cent of GDP investment in R&D by 2010. However, the latest available data on total expenditure on R&D as a percentage of GDP in Ghana around 0.4% is relatively low. There is the need for government to increase its budgetary allocation to STI.

3.2 Innovation activities among Ghanaian firms

Ghana has an innovation rate of about 72.5 percent and is among other African countries such as Kenya, Senegal, Nigeria, Tanzania and Gabon that introduced both technological and non-technological forms of innovation in their firms' activities (OECD, 2014). However, only 27.7% of the innovation activities exist as still ongoing with about 22.3% abandoned/delayed (Tetteh and Essegbey, 2014). Firms' expenditure on innovation activities as well as firms' collaboration on innovation activities were used as indicators on innovation performance and described in the following sub sections.

3.2.1 Expenditure on innovation activities

Innovative activities undertaken by Ghanaian firms included Research and Development (R&D) activities (intramural, extramural, occasional and continuous), acquisition of machines, equipment and software, acquisition of external knowledge, marketing and designing (NEPAD/STEPRI 2012). Expenditures on these activities are important indicators of innovation performance as there is a direct positive connection between R&D investment and levels of economic development and growth (Martino, 2009). As companies create, disseminate and apply knowledge they boost economic expansion. As shown in Figure 1, Intramural (in-house) R&D and acquisition of other external knowledge accounted for 38.2% and 24.1% of expenditure on innovations respectively during 2008 to 2010 (NEPAD/STEPRI 2012). This constituted the largest share of expenditure on innovations in Ghana. The expenditure was followed by extramural (outsourced) R & D and acquisition of machinery, equipment and software with 19.1% and 18.6% respectively.

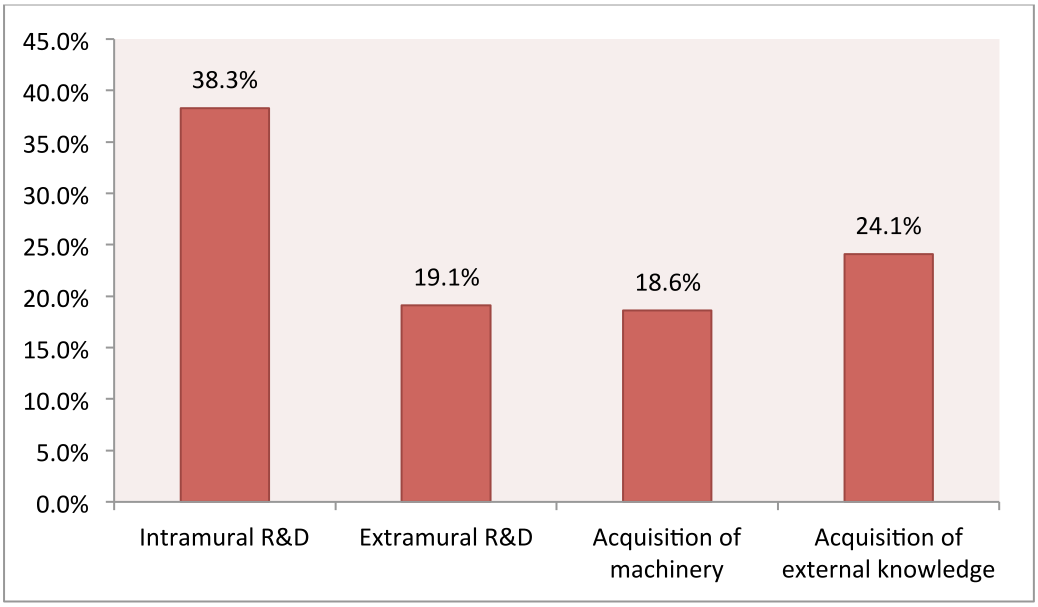

Figure 1: Firm's share of innovation expenditure
Source: NEPAD/STEPRI 2012

The extent of firm investment in innovation activities in Ghana needs to increase. OECD (2000) shows the total expenditures for industrial R&D by SMEs and indicated that, the total expenditure has increased by almost three times between 1985 and 1995 in the United States. It also found an increase in the R&D-sales ratio for SMEs as well. To this extent, United States is a model country to emulate. UNESCO (2007) report have indicated that, Ghana's private sector spending on R&D was approximately 20.0% of total R&D expenditure which is on the low side. There is the need to apt this to improve the performance of innovation. Other innovation activities such as knowledge acquisition also need to be harnessed as good human capital is important for the promotion of innovation. Goedhuys et al. (2008) have also explained that, firms in developing countries operate substantially below the technology frontier with lower levels of human capital which implies that, with good human capital, these countries including Ghana can catch up in the technology acquisition and in addition even rapidly scale up products to market.

3.2.2 Firms collaboration on innovation activities

At the national level, understanding the linkages among institutional actors involved in innovation activities or processes is vital to improving a country's technological and economic performance. According to Figure 2, only few Ghanaian firms collaborate in their innovation activities. Out of the ones that collaborate, only 0.4% had formal collaboration with R&D institutions such as universities and other educational institutions and government/public research institutions. This implies that, most of the cooperation were informal in nature and was from sources within enterprises' group, suppliers, clients/customers, consultants, and even other competitors within Ghana and other countries.

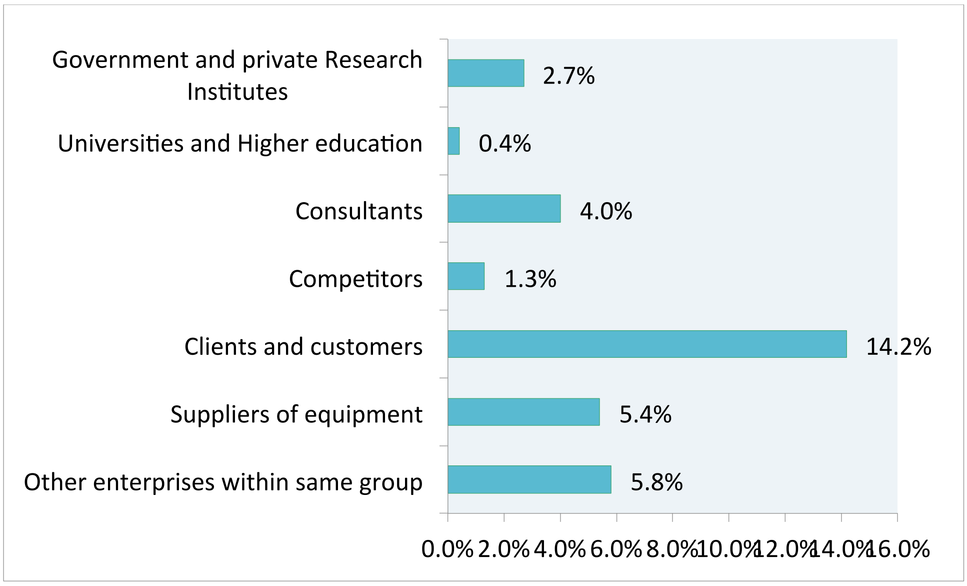

Figure 2: Firm's collaborations on innovation
Source: NEPAD/STEPRI 2012

Various studies have also identified weak linkage between research institutions and the private sector (Zachary, 2003; UNCTAD, 2003 and UNESCO, 2007). More specifically, UNCTAD notes that, Ghana's Institute of Industrial Research under the Council for Scientific and Industrial Research (CSIR - IIR) do not have a strategy for reaching out to a broader range of businesses and entrepreneurs, or for linking its programme activities to the needs and demands of the industrial production sector. Its activities are essentially supply-driven and dictated by the limited range of in-house expertise. Zachary (2003) also noted poor linkage between university faculties and the private sector as many companies do not seem to be interested in or to value R&D type partnerships and most SMEs largely adapt or modify existing goods or services with foreign large corporations conducting R&D in their home countries. The intensity, diversity and effectiveness of interactions (linkages) between the main actors involved in the generation and diffusion of knowledge are important factors in innovation performance (UNECE, 2012). They can be of both a formal and an informal nature but the nature of the linkage reflects the development stage of influencing factors as the linkage is crucially influenced by the embedded incentive structure of the national innovation system. According to UNCTAD (2012), a well-functioning innovation system can quickly diffuse new information, ideas and technologies among enterprises and other actors in the system improving the performance of innovation. They are needed to promote a more dynamic and innovative private sector and drive growth in an industry and in the economy at large.

3.3 Constraints to innovation in Ghana

The innovation systems of Ghana under the STI Policy Review identified significant weaknesses which are bottlenecks for innovation performance both at the firm and country levels in the country (UNCTAD 2012). The weaknesses included:

- Poor institutional configuration and leadership: There is no agency for promoting the procurement and use of old and new technologies. The institutions are neither well connected nor communicating to effectively drive technological development in economic activities.
- Lack of an explicit national innovation policy and related strategy: Ghana's science, technology and innovation policy measures have to a large extent been implicit and scattered in many government documents. There is a lack of policy coherence and focus on innovation.
- Limited funding is channeled to the country's STI programmes: Ghana's budget and expenditure on R&D and related innovation activities are too limited. The country is not sufficiently targeting innovation in either the public or the private sector.
- Institutions of education and training are not producing human resources of the required quality and quantity to spur technological innovation for economic growth.
- Inadequacies in physical infrastructure (e.g. unreliable and costly electricity) are a major barrier to technological innovation in both public and private enterprises.

Factors highlighted as challenges hampering innovation activities among Ghanaian firms are categorized according to cost factors, knowledge factors, market factors, other factors and no need to innovate. From Figure 3, other factors which constitute factors such as organisational rigidities within the enterprise, workers not having the incentive to innovate, insufficient flexibility of regulations or standards, limitations of science and technology public policies, weak intellectual property rights protection as well as some practices used by informal firms mostly affected innovation activities (NEPAD/STEPRI, 2012). This was followed by cost factors such as lack of funds both within and outside the enterprises and high innovation cost. Knowledge plays a crucial role in innovation activities and factors such as difficulty in finding partners for innovation and inadequate qualified personnel and information on technology were important. Perceived market factors included domination of the market by established firms as well as firms' uncertain demand for innovative goods or services. Other firms also found no need to innovate. As earlier stated, improved performance of innovation have the potential in accelerating growth and development and in effect reducing poverty. Therefore, there is the need to improve and to create an enabling environment through effective policy formulations and implementations to accelerate the performance of innovation among the firms and mitigate the weaknesses and constraints identified within the system.

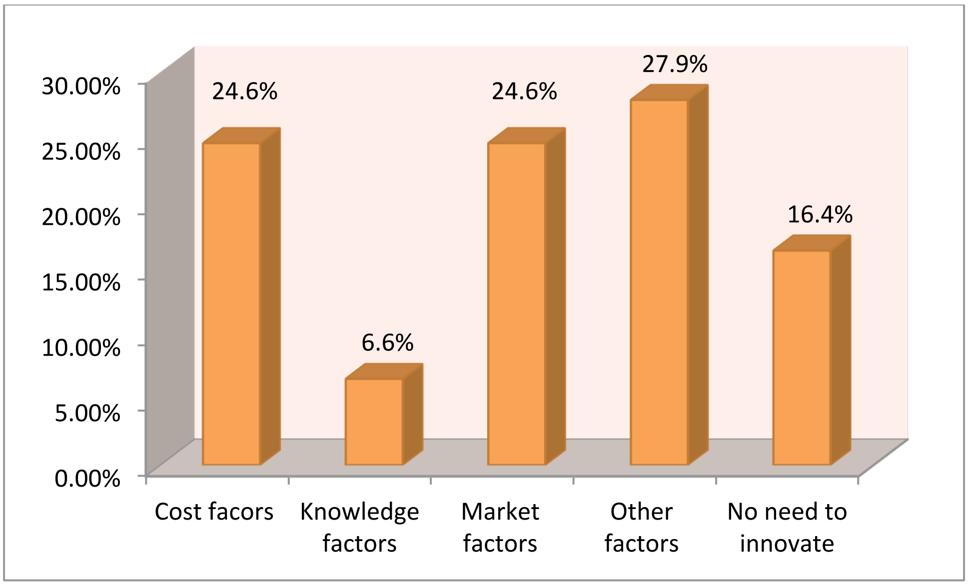

Figure 3: Factors challenging innovation activities
Source: NEPAD/STEPRI 2012

3.4 Opportunities for innovation growth in Ghana

Ghana's institutional landscape has at least sixteen R&D institutes, seven public universities, a number of private universities, ten polytechnics, several technology support and regulatory agencies, and at least a dozen commercial and development banks (UNCTAD, 2012). These institutions characterises the NIS of Ghana and linkages between the institutions and policies explicitly put in place promotes technological innovation for economic growth. NIS operates to provide enabling environment for private sector technological development as well as foreign direct investments which are the two key prospects that provides opportunities for Ghana's innovation promotion and development. As depicted in Table 2, the rate of FDI in Ghana has grown since 2005 and still on the rise (UNCTAD, World Investment Report 2016)

Table 2: FDI growth rate in Ghana (2005 – 2015)

FDI INFLOWS	2005-2007	2013	2014	2015
% OF GDP	12.1	29.6	36.0	37.9
$MILLIONS	545	3226	3357	3192

Source: UNCTAD World Investment Report 2016

The private sector in Ghana is very attractive and Ghana has impressively progressed in the ease of doing business rank achieved, which was 94 in 2007 and is 67 in 2014 (Doing Business Report 2014). As noted, policies towards the sector aim at creating a more business-friendly economic and regulatory environment. The Trade Policy exists for Government to seek and attract foreign investment and promote exports. National Export Strategy within it emphasizes on the Non-Traditional Export Sector and a national Export Development Programme. Also, the Industrial Policy exists to create and promote a modern productive economy, with high levels of value addition and agro-based industrial development; to expand productive employment and technology capacity in the manufacturing sector as well as promote spatial distribution of industries in order to achieve reduction in poverty and income inequalities. The Legislative aspect responsible for Intellectual Property (IP) Protection Legislation under Patent Act 2003, Industrial Designs Act 2003, Copyright Act 2005, Trademarks Act 2004, Geographical Indications Act 2003 and Layout Designs of Integrated Circuits Act 2004 with the Registrar General's Department (RGD) which is the focal point for IP protection matters pertaining to patents, industrial designs and trademarks and Copyright Office also responsible for issues related to copyrights constitute the legal framework of the NIS supporting innovation in Ghana.

It is therefore important to note that, the linkages and interactions among the various institutions in a national system of innovation can be purposefully stimulated and nurtured by public policies and various incentives that government puts in place. Public policies pertaining to STI development, intellectual property protection, competition, FDI, trade, taxes, mobility of scientists and engineers, and technology regulation and licensing can all influence the evolution and growth of an innovation system.

4.0 Conclusion and Policy Recommendations

The paper indicated that firms within Ghana are innovating at a good rate but with high proportion of abandoned innovation activities and low on-going activities, which require more efforts to enhance them. Low firm investment in R&D, inadequate public/government financial support to firms to undertake R&D activities and weak linkages between and among institutions in the innovation system were evident. Factors highlighted as hampering innovation activities within the firms mainly included both internal and external factors. However, the greater the technological opportunity, the bigger the incentive for firms to invest in R&D and innovate hence several institutional, legislative and policy measures supporting innovation activities exist in Ghana which are opportunities for growth. FDI and private sector development are prospects for innovation growth therefore the need to provide incentives targeted at areas such as urban development, improved export services and infrastructural development for the enterprises to thrive and to attract FDI.

It is imperative to make policy recommendations to increase the efficiency of the NIS of Ghana and enhance the innovation capabilities of firms. The paper recommends further efforts to strengthen the connectivity between various components of the National Innovation System to facilitate linkages between the main actors involved in the generation and diffusion of knowledge and innovation. Further efforts into formulating explicit policies and strategies to promote innovation in Ghana will be extremely useful. This would in effect improve the framework conditions for innovation, by addressing existing constraints to innovation activities and further improving the business environment to make it more conducive for innovative entrepreneurship. The role of research institutions and other knowledge-generating organizations in the National Innovation System should be strengthened by boosting their capacity to transform ideas into innovation projects and reinforcing links with other innovation agents. Finally government's budget and expenditure on R&D should be improved and national funding for innovation activities be introduced to foster financing of innovative entrepreneurs and support R&D as well as provide micro financing and small grants to SMEs to encourage innovative activities among them.

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