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Public-Private Partnerships in Research and Innovation

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Abstract

In the transition to knowledge-based economies, the role of knowledge is at the pinnacle of trade, investments, manufacturing and socio-economic development. Public-private partnerships (PPPs) in research and innovation present an opportunity for co-creation and exchange of knowledge and associated products with the private sector. In the context of the Science Granting Councils Initiative (SGCI), PPPs refer to the linkages between the publicly funded research entities on the one hand, and industry, particularly the manufacturing sector, on the other hand. To promote the co-creation and exchange of knowledge and associated products between the public and private sectors, the SGCI and the science granting councils (SGCs) in sub-Saharan Africa (SSA) instituted a Public and Private Partnership Research and Innovation Grant Scheme. This chapter looks at the activities of these schemes in Malawi and Uganda using a case study approach of five projects funded across the two countries. The analyses of the cases are presented alongside four over-arching sub-themes: (i) stakeholder engagement; (ii) institutional strengthening; (iii) contribution to policy processes;

and (iv) organizational culture and practices. A final concluding section looks at the lessons and prospects for the future as the emerging findings on new technologies and products; new business opportunities; and the diversified use of locally available raw materials.

Introduction

The demand on universities and public research institutes to become more entrepreneurial and build linkages with private sector has been on the increase since the early 1990s (Caulfield, et al., 2012). This has been attributed to the decreasing support for universities from government as well as the transition to knowledge-based economies (Downie, 2006). This demand behoves universities and public research institutes to produce research with commercial potential and interact more closely with the intended beneficiaries of their research (Goransson and Brundenius, 2011). Opinion is divided on whether this emphasis on commercialization of university research is good, with protagonists arguing that it will: (i) allow universities to have more direct impact on the lives of its beneficiaries; (ii) increase the researchers' income and prestige; and (iii) allow exchange of knowledge with industrial actors. The antagonists have pointed out that: (i) close associations with industry will erode the universities' focus on broader social goals; and (ii) this entrepreneurial culture may dictate the exact nature of research done in universities with a potential over-emphasis on research that lends itself to commercially viable innovations in the short to medium term, a situation that may disadvantage basic research (Kumar, 2010).

The public-private partnership (PPP) arrangements have immediate influence on the conduct of scientific research and how the findings of such research are made available to stakeholders, particularly the private sector and other beneficiaries. Of immediate interest to this chapter is the commercialization and related impact pathways to technology development and knowledge exchange. The commercialization debate dates back to the post second world war period with the publication of the Vannevar Bush report *"Science: the endless frontier"* (Bush, 1945), in which he argued for steady federal funding for basic research *"so that university researchers could engage in research free from the adverse pressure of convention, prejudice or commercial necessity"*. The publication of the Bayh-Dole Act in 1980 in the USA is considered a turning point in the appropriation of academic research, produced through government funding. It permitted universities to obtain patents on research done with federal funding and exploit such patents for commercial use.

In many African countries, the emphasis towards commercialization of research has resulted in a number of institutional and organizational realignments in the universities and public research institutes. For example: (i) new structures in the form of technology transfer offices (TTOs) or intellectual property management offices (IPMOs) have been created; (ii) new offices and titles have been introduced into the university management structures, for example, the office of Deputy Vice Chancellor (Research and Innovation); (iii) new companies attached to or owned by universities; and (iv) science and technology parks and incubation centres.

At the national level, there's renewed emphasis on innovation (application of knowledge) both in national policies[1] as well as in government funding instruments.[2] Outside government, new intermediary organizations dedicated to enhancing academia-industry linkages have emerged.[3] Similarly, donor-supported interventions such as the knowledge transfer partnerships (KTP) in Kenya and Rwanda supported through DFID/UK have resulted in technologies and innovations licensed to the private sector. These developments at the national (policy), organizational (institutional) and partnership (operational) levels have effects on the opportunities for follow-on innovation and participation in new collaborations.

In the context of the foregoing, this chapter: (i) examines the conditions under which public-private partnerships lead to development of new innovations and technology transfer; and (ii) presents evidence to inform the practice of establishing and governing effective PPPs geared towards addressing innovation and commercialization. The chapter is based on practical experiences and case studies of contemporary public-private partnerships in Uganda and Malawi, and highlights experiences and good practices which can strengthen the intermediary role of councils in fostering PPPs to enhance commercialization of research findings. The key questions being answered by this chapter are:

(a) How have PPPs in research and innovation contributed to the development of new products and services?

(b) What are the existing good practices of effective PPPs in research and innovation in Africa?

(c) How have the PPPs enhanced the capacity of councils in catalysing, facilitating and mediating PPPs for research and innovation?

Research methods and approach

Contemporary case studies of PPPs in research and innovation

The concept of PPPs in research and innovation (R&I) as implemented under the SGCI-1 projects emphasizes the principles of *co-investments* (of financial and non-financial resources), *co-creation* of knowledge and *co-application* (through commercialization and other uptake pathways). As such, building PPPs has been hailed as effective in combining skills, competencies and expertise to overcome their individual actor limitations (Kania and Kolk, 2013). PPPs fulfil several other sustainable development functions including knowledge production, information and innovation; dissemination of knowledge and good practices; technical implementation; institutional capacity building; standard setting and certification; lobbying and advocacy; and technology transfer, among others (Pattberg et al., 2012).

There are various motivations for actors entering into PPPs as a commercialization pathway including: (i) access to knowledge, expertise, skills, networks and contacts; (ii) access to funding; (iii) improved stakeholder relations; (iv) improved reputation and credibility; (v) increased operational efficiencies and effectiveness; (vi) creation of more appropriate services and products; (viii) access to and knowledge of new (future) markets; (viii) access to and more insight into business operations, current markets and supply chains; and (ix) increased leverage/impact (Rondinelli and London, 2003).

Such motivations often (but not always) result in: (i) joint programming; (ii) knowledge transfer; (iii) research commercialization; and (iv) collaboration between universities, national research institutes and business communities which can encourage stronger and productive partnerships between the public and private sector. Effective PPPs have the potential to increase public sectors' responsiveness to the transformation of innovation processes and associated private sector needs and strategies, as well as to enhance the translation of research outputs into innovative products.

To interrogate these issues, the chapter adopts a case study approach (Yin, 1994; Thomas, 1998) and uses contemporary case studies.[4] The cases to be studied have been selected to reflect: (i) different commercialization and uptake pathways; (ii) different economic sectors or themes; and (iii) geography and location (East Africa, Southern Africa).

Consistent with the case study approach, the chapter follows a largely qualitative design involving a systematic collection, organization and interpretation of material derived from document reviews, interviews, and monitoring and evaluation (M&E) reports.

Our study design triangulated a number of methods involving: (i) document reviews in which a number of key policy and strategy documents were consulted; and (ii) issues emanating from initial documentary review (mainly of policies and strategies) were put to selected practitioners and policymakers through short, exploratory key informant interviews (KIIs): the key informants comprised the project coordinators (PIs in the selected PPP projects; SGCI coordinators in the selected countries; and other identified experts in the areas under investigation). The KIIs were conducted through a short questionnaire administered through a survey monkey. The KIIs were a precursor to more in-depth focused interviews with representatives and coordinators of the science granting councils (SGCs).

The use of in-depth interviews allowed the research team to obtain tacit knowledge including how decisions were made in the partnerships and the influence and details of the application of the rules and policy guidelines; it also helped to elicit the perception of individuals and groups on the institutional context, role of different actors, coordination and role of government agencies, governance and decision-making. The in-depth interviews focused primarily on the councils – their mandate and role in collaborative research especially in the context of the contemporary PPP projects; their constraints and capacity strengthening requirements; and their policy advisory role and the support required to enhance partnerships and collaborations.

For analysis, we define the outcomes from the projects at three different levels: (i) internally, on the work and capacity of the implementing organization; (ii) externally, on the attitude, behaviour and practices of the partners and community; and (iii) contribution to project objectives. On the first level – institutional strengthening – we describe how the projects have added value to the institution through positioning for future work (in similar and related areas); and human skills development as well as infrastructural enhancement. At the second level, we detail whether the project findings had any policy implications. If so, what policy processes did the project engage with and what approaches were used to engage policymakers and policy contribution to processes. We also interrogated whether new partnerships and collaborations arose from the projects.

Flowing from the above, four sub-themes present themselves for the analysis of our case studies:

- Stakeholder engagement (especially the private sector)
- Contribution to policy debates and processes
- Community building including new networks, partners and consortia
- Changes in organizational culture and practices – attitudes,, knowledge, skills and motivations of project partners and stakeholders.

Case study summaries

The first case study, *"High fibre bakery and confectionery products from maize germ and bran"* focuses on the utilization of abundant maize bran and germ generated by the different millers in product development for bakery and confectionery enterprises. The commercial potential of the project is based on the ever-increasing demand for maize, hence resulting in bran and germ availability. The production of baked and confectionery products in Uganda is currently dominated by the use of refined flours with low fibre content and are highly priced. The project aimed to incorporate bran and germ into various baked and confectionery products such as muffins, bread and cookies. These products are differentiated from the existing products owing to their high fibre content and associated health benefits.

The project is led by Makerere University's Department of Food Technology and Nutrition and targets maize millers who produce bran and germ as by-products. In particular, the project's private partners include: (i) Maganjo Grain Millers – producing a range of milled cereal flours, extruded breakfast and snack food; (ii) Agro ways (U) Limited – producing maize grit; and (iii) JOVAY School of Cookery – producing a variety of bakery and confectionery products. The major beneficiaries of this project are the millers who generate bran and germ; the bakery and confectionery enterprises; and the consumers who enjoy high fibre foods. The consumer demand for health products provide the springboard for uptake and utilization of knowledge generated by the project.

In the second case study, the project *"Commercial exploitation of propolis and bee venom in Uganda"* aims at developing propolis and bee venom-based products including: propolis powder supplement, bee venom powder supplement, a syrup drink and a ready-to-drink beverage. The School of Veterinary Medicine and Animal Resource-

Research Center for Tropical Diseases and Vector Control (SVAR-RTC) at the College of Veterinary Medicine, Animal Resources and Biosecurity (COVAB)-Makerere University, have partnered with private sector players such as the Uganda National Apiculture Development Organization (TUNADO) which has a network of 9,000 beekeepers and Aryodi bee farm with a network of 500 producers, an already running business with between 10,000 kg and 15,000 kg of honey per season.

In the third case study, the project *"Cocoa waste to wealth using yeast strains from Ugandan box fermentation"*, aimed to develop a single cocoa fermentation box to help small-scale farmers who cannot generate large quantities of cocoa beans required in storey box fermentation. The single fermentation box requires less capital and is gender inclusive. The project also proposed the use of yeast starter with pectin hydrolysing properties to aid extraction of cocoa juice from cocoa pulp using a stainless-steel tank with a hydraulic press. The development of value-added products such as ethanol and wine from cocoa pulp juice and sweating is expected to reduce Uganda's ethanol importation costs which stood at US$500,000 in the year 2015. Additionally, the project was expected to boost income generating capacity of participating cocoa farmers in varying agro-ecological zones of Uganda by up to 25 per cent through sale of value-added products to laboratories and well fermented cocoa beans to cocoa buyers, thus fetching better prices. This project was led by the National Coffee Research Institute (NACORI) in collaboration with the private actors in the cocoa industry namely ICAM Chocolate and Lwanga enterprises.

In the fourth case study, Tsangano market in Malawi is associated with huge quantities of vegetable waste which most of the time is dumped in open space. This has adverse effects on the environment, climate and human health. However, vegetable waste is a valuable resource for biogas production. The project is premised on the fact that production of biogas at the market would help to provide an alternative source of energy for cooking to restaurants, chips making businesses and households. Additionally, use of biogas will help to reduce deforestation, and promote sanitation at the market and in the surrounding communities.

In the fifth case study, the innovative solar-powered milking machine technology was not available to smallholder dairy farmers in Malawi. This necessitated research intervention to assess the feasibility of incorporating renewable energy in milking dairy cattle. The design of

the solar energy powered systems was done, and solar-powered milking machines and solar-powered water pumps were installed and operated.

Case studies of agro-processing in Uganda

Case study 1: High fibre bakery and confectionery products from maize germ and bran[5]

Maize is the most important cereal food crop supporting about 86 per cent of the 4.2 million agricultural households in Uganda. Processing maize into refined flours results in large amounts of bran and germ as by-products. These are widely used as animal feed but are not yet considered as human food. Maize bran remains the richest source of additional fibre and contains various minerals which are vital for the proper functioning of the body and in the prevention of constipation. Maize germ, on the other hand, is highly nutritious with essential oils, vitamins and proteins. Maize bran and germ, when used in product development can impart a number of health benefits.

At the moment, the two by-products of industrial maize milling – maize germ and maize bran – are considered of low economic value and have dominated the animal feed production sector, hence not been considered as human food. In this project, different ratios of bran and germ have been used to produce bread, cookies and cakes. These products have been tested for both sensory and chemical properties. Wheat flour was replaced by maize bran, maize germ and soy flour at different levels of 0 per cent, 10 per cent, 20 per cent, 30 per cent and 40 per cent to produce enriched balanced bread. Preliminary results indicate that mixing bran, germ, soy and wheat can produce an acceptable product. At 30 per cent substitution, the bread had the highest loaf weight and crumb hardness. At 20 per cent substitution, the bread produced had the overall good general appearance and acceptability. With respect to aflatoxin content, all bread tested had less than 0.005 ppm. As the project progresses, further formulation experiments are being conducted to produce more bread, cookies and cakes.

Case study 2: Commercial exploitation of propolis and bee venom[6]

In Uganda, the proportion of people that are immune-compromised owing to factors such as malnutrition, communicable diseases and stress are rising. Bee products such as propolis and venom are known to be medicinal. In Asia, Europe and USA, propolis and venom have been processed and commercialized as medicine and food supplements. In Uganda, only 1 per cent of propolis is crudely harnessed by cottage

enterprises that have ventured into production of supplements and beverages enriched with propolis or bee venom. However, the production (extraction) processes and quality of the products not only vary but are also not known. Thus, the need to standardize and optimize the processes, and develop prototype products for the growing Ugandan market.

This project aimed at contributing towards income and food security through diversification into high value products of honeybees such as propolis and bee venom. The household income contribution of beekeeping is limited at only 7 per cent (Amulen et al., 2017). Yet bees offer numerous products that are of high medicinal and commercial value such as propolis and bee venom. However, with all the numerous benefits of the high value products, their exploitation within Uganda remained low. To significantly improve the contribution of beekeeping to rural household incomes there is need to improve production and extraction of non-honey products such as propolis and bee venom, and create high value ingredients out of them for food supplements, beverages, cosmetics and pharmaceutical products. In addition, the available cottage industries that had ventured into production of propolis and bee venom had limitations in their production (extraction) process and quality of the products. These products greatly varied, and most times had unknown composition. Based on the foregoing, this project aimed at standardizing and optimizing the processes, and developing prototype products for the nascent Ugandan market. The project works with existing private enterprises to develop and promote supplement and beverage product prototypes for improved commercial exploitation of propolis and bee venom in Uganda.

Case study 3: Cocoa waste to wealth using yeast strains from Ugandan box fermentation[7]

Cocoa ranks fourth in foreign revenue contributions and supports over 10,000 households in Uganda. Cocoa is harvested as pods, broken open to remove the white mucilaginous pulp which consists of water, sugars, pectin and organic acids that act as the fermentation media. In Uganda, cocoa fermentation is carried out spontaneously by unidentified microorganisms using either storey boxes or heaps; this leads to product and price variability. NACORI has isolated pure yeast strains from Bundibugyo and Kayunga districts that could be used to generate controlled fermentation to attain better quality beans. In Uganda, the storey box method of cocoa fermentation is mostly afforded by

commercial exporters since it requires huge capital investments and large volumes of beans (over 100 kg) to attain quality results. This forces small-scale farmers to sell fresh beans with no value added. This is the gap that this project aims to fill.

Fermentation is one of the vital steps that ensure the development of chocolate flavour precursors and thus determines not only the quality of resultant chocolate and prices offered to farmers. The fermentation methods that are currently used require huge volumes of cocoa pulp (over 400 kg) to achieve the desired quality, leaving small-scale farmers with no option but to sell their cocoa fresh at a low price. During cocoa fermentation, a lot of waste is generated as sweating from fermentable juices that can be detrimental to the environment by affecting soil pH. The project is tackling the above challenges by designing a single cocoa fermentation box that handles smaller volumes (40 kg and more) and a stainless-steel press for extraction of juice from cocoa pulp that can be fermented to generate value-added products such as wines and ethanol. This is expected to boost income generating capacity of cocoa farmers and lessen the negative impact on the environment.

The first prototype of the single fermentation box has been developed and efficiency studies are being conducted in Kasawo alongside a storey box fermentation method. A temperature profile for both methods has been obtained. Full fermentation of cocoa beans was achieved after 144 hours in both methods. Preliminary results have shown that the single fermentation box will be a better alternative cocoa fermentation method for small-scale farmers. Similarly, a cocoa juice extraction press with a capacity of 15 kg has been designed and fabricated, and production of value-added products from cocoa juice has commenced.

Case studies of renewable energy in Malawi

Case study 4: Piloting biogas as a social enterprise at Tsangano vegetable market, in Ntcheu District

Tsangano market located in Ntcheu District is one of the largest vegetable markets in Malawi. The market supports both Malawian and Mozambican vegetable farmers. However, the market is associated with huge quantities of vegetable waste. The market lacks proper infrastructure and facilities for waste management, and as a result waste is dumped in open space. This has adverse impacts on the environment, climate and public health. However, biodegradable materials such as vegetable waste are a valuable resource that can be used to produce biogas for cooking. At the market, the demand for heat energy by chips

makers and restaurants is very high. Therefore, biogas produced will be supplied to such users at a fee. The use of biogas will also help to reduce deforestation at Tsangano and the surrounding areas. Organic fertilizer is a by-product of the biogas production process, which will also be made available to vegetable farmers. Organic fertilizer will be packed and sold to smallholder vegetable farmers. The market potential for organic fertilizer is high as the price of inorganic fertilizer keeps on increasing in Malawi. The use of waste as a raw material for biogas and organic fertilizer production will also help to solve waste challenges at Tsangano market. In the long run, it is expected that biodegradable waste will become valuable raw material that can be traded.

The overall goal of the research project is to promote biogas development for socio-economic development and environmental sustainability in Malawi. The project seeks to pilot "Fee-For-Service Social Enterprise Business Model" in biogas. The entrepreneurship component of the project will help to generate funds for operation and maintenance of the biogas plants. It is expected that this approach will help to address the problem of project failure, which mostly happens with energy projects given as a gift to communities in Malawi. The expected outcomes of the project are: (i) increased knowledge on biogas as a social enterprise; (ii) biogas as a clean and alternative source of energy promoted; (iii) increased use of organic fertilizer at Tsangano; and (iv) improved sanitation at the market and surrounding areas.

Malawi University of Science and Technology (MUST) implemented this project in partnership with a local energy company, Green Impact Technologies (GIT). The project also engaged the Malawi Government and other stakeholders such as non-government organizations in order to influence a change in policy.

Case study 5: Solar powered technologies for smallholder dairy industry[8]

Malawi's dairy industry is dominated by smallholder farmers estimated at a population of 7,000 who produce the bulk of milk that is available for processing. However, the farmers do not have access to electricity, reliable power or energy sources to modernize their farming activities such as milking and water supply. Milking is done using hands and most of the farmers do not have a reliable supply of safe water for watering cows and for maintaining adequate levels of hygiene and sanitation. Consequently, the smallholder dairy industry is characterized by low milk production and poor milk quality resulting in huge actual and potential financial losses.

Machines can safely be used for milking cows if proper hygiene is maintained. Thus, a steady supply of clean water is mandatory for proper utilization of milking machines and hence the need for water pumps. The operation of milking machines and water pumps requires energy which is generally inaccessible to Malawian smallholder dairy farmers. As of 2014, access levels to grid electricity in the country were lower than 2 per cent in rural areas where smallholder dairy farming is done. Nonetheless, Malawi has a high solar energy potential which can be introduced into the country's smallholder dairy industry.

The overall objective of this project was to contribute towards improved milk production among smallholder dairy farmers in Malawi through the introduction of two innovative solar-powered dairy production technologies: (i) solar powered milking machines which are neither available at the local market nor utilized in smallholder dairy production systems; and (ii) solar-powered water supply systems which are currently not used in the smallholder dairy production systems. The project was piloted in Lilongwe and Dedza districts and targeted smallholder farmers, solar energy technology dealers and local milk processors. The project was jointly implemented by LUANAR and a Malawian registered private company – Orifice Irrigation and Water Supply (OIWS) Limited – which specializes in supply and installation of solar energy technologies and water supply systems.

Opportunities, approaches and outcomes

Opportunities for innovation and intervention

Maize germ is highly nutritious with essential oils and proteins that are necessary for the human body. When plain maize bran is added to a recipe, it greatly increases the fibre content. It can be used in products like cereals, chips, or snack bars, to increase the fibre. It has a minimal impact on calorie count, so foods designed for dieters can be made with bran to keep the calories low and give the food a filling notion. Fibre contains various minerals which are vital for the proper functioning of the body and prevention of constipation. In view of these facts, value addition to maize germ and bran becomes a key area of nutritional intervention leading to the utilization of the large amounts of bran and germ generated during production of maize flour.

One of the key challenges in the bee project was low supplies of propolis in the dry season from the Lango sub-region. However, using the TUNADO broad network, the project team opted to expand the

geographical collection of propolis for product development. A key opportunity from this project concerns the need to develop specialized propolis collection equipment for Ugandan beehives such as log hives. This will increase yields per hive. Another specialized equipment needed is a mechanical churning machine to accelerate the time of powder extraction and increase yield. Currently, the churning is by hand and produces only 7 per cent yield per kg. Lastly, one of the exciting findings of the project is that for the first time, the project has documented the presence of black and red propolis in Uganda, which provides a basis for further assessment and analysis, especially with respect to determining if there are variations in their antibacterial properties. This project is the first to launch the propolis powder and juices in the Ugandan market.

Cocoa is harvested as pods, broken open to remove the white mucilaginous pulp which consists of water, sugars, pectin and organic acids that act as the fermentation media. In Uganda, cocoa fermentation is carried out spontaneously by unidentified microorganisms using either storey boxes or heaps; this leads to product and price variability. The storey box method of cocoa fermentation is mostly afforded by commercial exporters since it requires huge capital investments and large volumes of beans (over 400 kg) to attain quality results. This forces small-scale farmers to sell fresh beans with no value added. This is the gap that this project aimed to fill.

In Malawi, the private sector has not been actively involved in biogas development. Biogas is mostly given for free to communities as a way to address energy, deforestation and environmental challenges. The approach is not sustainable, so as a result, some biogas projects have failed to achieve the intended results. The biogas project piloted a Fee-For-Service Social Enterprise Business Model which involves commercialization of social services. Under this model, services are sold directly to the target populations, individuals or communities. Based on the project pilot results, the partner company, GIT will replicate the enterprise to other potential areas. This will help to promote biogas development and increase access to clean energy.

Approaches to innovation and technology uptake

The maize germ and bran project utilize locally available raw materials that have been considered to be of low human value and dominate the animal feed sector. The raw materials used to make bread were wheat flour, maize bran, maize germ, soy flour, fat, sugar, yeast, salt and water. Soybean grain was purchased from Soybean Africa Ltd., a local soybean

company along Gayaza-Zirobwe Road, the grain was thoroughly sorted, and extraneous materials removed, roasted and milled by Kayebe Grain Millers, another local milling company in Kasangati. Maize bran and maize germ were obtained from Maganjo Grain Millers Ltd., a local grain milling company in Kawempe, while wheat flour, yeast, fat, sugar and salt were obtained from Kikuubo Market in Kampala. Wheat flour was replaced by maize bran, maize germ and soy flour at different levels of 0 per cent, 10 per cent, 20 per cent, 30 per cent and 40 per cent to produce enriched balanced bread. Maize germ was substituted in the range of 4 to 15 per cent and maize bran in the range of 1 to 10 per cent. All formulated breads were baked in an oven set at 200°C for 30 minutes.

To obtain the above results the *bee venom project* baseline surveys were conducted to capture current practices, product profiles, economic viability and opportunities for improvement of the product. Further, 140 samples of propolis and venom were collected from four regions for laboratory analysis to determine composition and safety. Two product prototypes (drink infusion of propolis powder and beverage drink) have been formulated to be up scaled by the private sector partner (Aryodi Farm). Finally, the project trained 20 trainers under the Uganda National Beekeepers on hygienic handling of the new products.

A total of 140 propolis samples for laboratory analysis were collected, 450 kgs of propolis for product development procured, 140 survey questionnaires administered, and all entered in a database. A Masters student supported through research has completed presenting her proposal to the higher degrees committee at the School of Veterinary Medicine and Animal Resources and has been cleared to proceed and collect data. The Masters student conducted safety analysis for the propolis samples that were collected from beekeepers and apiaries to check for mycotoxins and also assess antibacterial properties. Two press releases in the Daily Monitor and New Vision newspapers were published.

The first prototype of the fermentation box was designed basing on the principle of the engine crank shaft. The first prototype was developed, and field tested to determine its fermentation efficiency alongside the tower fermentation method. Both single and tower fermentation boxes were loaded to capacity with cocoa pulp (50 kgs and 700 kgs respectively) and the initial temperature and pH recorded at 12-hour intervals. Temperature and pH were recorded at 12-hour intervals at three points of the box and mean obtained. A total of 200 g samples were taken

every 24 hours and kept in the refrigerator. The cocoa in both boxes was turned after every 48 hours: in the single fermentation box, the beans were turned by rotating the hand crank clockwise 360 degrees; while for the storey fermentation box, turning was done using a wooden stick to transfer it to the lower box. The beans were removed from both boxes on the sixth day (144 hours) and sun dried separately on a raised tray. These fermentation processes were done in according to the local practices. In addition, samples collected during the fermentation process were sun dried to a moisture content of 7 per cent for subsequent analyses. All the trials were conducted at the premises of one of the private sector project partners.

The biogas social enterprise is expected to contribute to the local economy in a number of ways. For example, what would have been waste will become a valuable resource which can be marketed, thus converting waste streams to income streams; community members will have an opportunity to collect, sort and sell waste for biogas production thus providing an alternative source of livelihood; biogas as an alternative source of energy will drive local business activities such as restaurants and chips-making business at Tsangano; organic fertilizer, a by-product of biogas production will boost agriculture and conserve the soil at Tsangano where agriculture is the main source of livelihood; and GIT will employ local people in biogas and organic fertilizer production and marketing.

Outcomes and key lessons

From the maize germ and bran project, the immediate outcome was the enhanced collaboration between the university and the private sector. This project fostered the collaboration between the miller (Maganjo Grain Millers Ltd.), the baker of confectionery products (JOVAY School of Cookery) and the university (Makerere University, Department of Food Nutrition and Technology). Further, both the university and the baking partner have purchased equipment that will strengthen both their research and innovation infrastructure, while two students will graduate from the project (one at Bachelor's level – completed and defended his research project; and another at Master's level – has collected data and is currently conducting analysis). It is anticipated that the work on the use of bran and germ may open up new policy discussions on their use in human food, especially the provision of high fibre products.

In the bee venom project, the team expected crushing and churning of propolis to be much easier and as such, simple kitchen aids like a

blender would work. However, it did not turn out as expected. Propolis is a sticky, hard substance that is harder to crush in large volumes. So, the team took time to crush some of the samples and this led to the recommendation for a mechanized churning machine for accelerated extraction of propolis powder.

The preliminary baseline survey results indicated that 90 per cent of the beekeepers were not harvesting propolis for sale and did not even know how to harvest or store the product. The few processors who bought propolis were poorly handling the raw materials by leaving it in open air instead of storing it in a dark dry place. All these confirmed the initial hypothesis that there was limited knowledge on handling of propolis and these bee farmers need to be trained, and awareness created about the opportunities the product can offer if harvested and handled properly.

The project found – for the first time – that there are two colours of Ugandan propolis powder (black and brown) even though it is yet to be determined, through further analysis, whether these two types differ in content of active ingredients. This new finding remains largely unknown and unexplored owing to the limited study of the product properties. Crushing and churning propolis gum is difficult and needs a mechanized crushing machine for quick industrial crushing; however, the project devised a means of freezing the product to remove the gummy and sticky nature before crushing. This was not earlier on hypothesized, so it is an emerging outcome from the project implementation.

From the cocoa project, a single fermentation box prototype was developed. For its operation, cocoa pulp is loaded into the box to capacity, door closed and top covered with a jute or sisal bag to avoid any external temperature influence. After 48 hours of fermentation, the hand crank is rotated clockwise (360 degrees) to turn the beans upside down. This helps to aerate the beans for growth of acetic acid bacteria. The commercial potential of the box will be determined after full evaluation in the different agro-ecological zones. Through the project, a student pursuing Bachelor of Science degree in agricultural sciences and entrepreneurship at Uganda Christian University was facilitated to carry out his special project research: *Evaluating Small Scale Cocoa Farmers' Fermentation Processes in Bundibugyo District.* The student has finished the research work and defended his dissertation, is awaiting graduation and is currently attached to NaCORI as a trainee.

Smallholder farmers in rural areas of Malawi have limited available energy to boost production of agricultural products for economic

development, yet Malawi's economy is agro-based and agriculture accounts for 36 per cent of the country's Gross Domestic Product (GDP), 90 per cent of Malawi's export earnings, and employs 70 per cent of the active labour force. The dairy industry in Malawi plays a significant role in providing employment and contribution to the GDP. Currently, Malawi's dairy industry is dominated by smallholder farmers who have no access to electricity to modernize their dairy farm activities such as milking. The smallholder sector has a total of about 7,000 dairy farmers with technical support from government and some NGOs.

Discussion and analysis

Stakeholder engagement: new and emerging networks and collaborations

From case study 1, two private sector partners have been fully engaged in the project. Makerere University as a public research institution is collaborating with Maganjo Grain Millers Ltd., producing large amounts of maize germ and bran, and Jovay School of Cookery, a small-scale bakery where formulation and product development activities are being undertaken. The two private sector partners have provided their premises for conducting the research. Maganjo Grain Millers are providing the maize bran and germ which they process to the specification of the project. Further engagement of the different stakeholders is planned during sensory evaluation of re-developed products, and when developing strategies for strengthening local capacity of local bakery and confectionery industries to use maize germ and bran as ingredients in product development.

In case study 2, new partnerships are emerging in the implementation process. The project has strengthened its networks with industry in areas such as branding and marketing to support Aryodi Bee Farm (the private sector partner) in proper packaging of the end product. The project team is also in discussions with metal fabricators to explore means of having a mechanized churning machine for accelerated extraction of propolis powder, reducing time from four weeks to three days and increasing yield from 7 per cent to 9 per cent per kg.

Makerere University as a public academic institution appreciates that better innovations are built together with communities and as one of the project team members notes: *"because under this project, we have been able to share ideas on how to improvise a local hive or specialized equipment for propolis production that beekeepers intending to become commercial propolis producers can adopt."*

In case study 4, the biogas project was implemented as a partnership between Malawi University of Science and Technology (MUST) and Green Impact Technologies (GIT) – a private sector company. The company was involved from the inception meetings, community mobilization, awareness, sensitization and actual construction of the plant. The involvement of the company in the project design ensured that after commissioning, it would take over, expand, sustain and replicate the technology to other areas where there are similar challenges of wastes problems, addressing deforestation and providing alternative energy for cooking.

In case study 5, the solar powered milking machines in Malawi project was led by the Agricultural Engineering Department (AGE) of LUANAR under a PPP arrangement with a private company, Orifice Irrigation and Water Supply Limited (OIWS). The two parties signed a Memorandum of Understanding (MoU) for the working partnership of the project. Under the partnership, responsibilities of each party and other logistical and management issues between the two parties were agreed upon. The PPP arrangement ensured that sustainability of the innovation was enhanced upon project completion.

Institutional strengthening

The projects have contributed to institutional strengthening through provision of equipment, thus improving the research and innovation infrastructure; increasing the visibility of researchers; training of students and providing opportunities to leverage more funding. The quotes below from project team members in case study 2 provide some insights:

> "*This project has improved our research capacity in the subject area. It has enabled us to acquire new equipment, mentor a student whom we hope to grow into a scientist in the field through her PhD work in the future. It has also placed SVAR-RTC at the fore front of high value product development as evidenced by the numerous calls from other private sector actors who need help on how to convert their propolis into powder.*"
>
> "*The administration is also considering adding us more workspace due to the visibility that this project has created.*"
>
> "*We have been able to mentor students and laboratory technicians. As scientists, our understanding of these products has also improved. Through the upcoming scientific meetings, we as scientists shall gain publicity. But it has also built a network between the university, communities (beekeepers) and private processors (Aryodi) including governing NGOs like TUNADO.*"

Furthermore, from case study 2 the team has reported that: *"as a result of the project initiatives, the PI was funded by US professional fellows to lobby for new funding in how to develop insect- propolis-honey based herb for child nutrition in agro-pastoral areas*". The project has also opened new funding opportunities within the university structures. Notably, as the team confirm: *"we now have an opportunity to apply to the university innovation fund because we have a pilot of our idea."*

The maize germ project has also reported that two students were recruited to undertake their Bachelor and Masters studies under the project. The Bachelor's student has completed and defended his dissertation while the Masters student is due to complete studies this academic year.

In case study 3, NACORI has been able to leverage additional funding and projects as a result of their PPP project. As they note: "*the work on fermentation box has attracted attention of MARK UP (an EU project) and NACORI has been given activity under the project to expand the scope of training farmers for improved cocoa fermentation*". This activity will focus on developing technologies for reduced pest and disease incidence, developing new cocoa varieties and designing appropriate technologies for improved post-harvest handling of cocoa. Furthermore, funds have been obtained through their Competitive Grant Scheme (CGS) at a tune of USh 100 million. This funding is focused at developing manuals to rehabilitate old cocoa fields and develop value-added products from cocoa.

In case study 5, one of the machines was installed at Bunda College Animal Science Students' farm and apart from being used for drawing lessons, it is being used for teaching animal science students in use of solar-powered milking machines. This will ensure sustainability of the technology because some of the students will work with dairy farmers when they graduate, while others may be in policy making positions. Sustainability of the innovations will also be ensured through the linkages made by the project team. The project team linked up farmers with agents providing back-up services to ensure after-project services for the innovation. The project team also provided training to the farmers both during and after implementation of the solar powered equipment project to ensure sustainability of the innovation. The involvement of the PPP partner (OIWS) is also very key in ensuring that the technologies are sustainable. OIWS will continue to market the technologies as a business entity, thereby also providing additional backup services to farmers with the technology.

Contribution to national policy processes

> *"We have contributed to developing standards in handling propolis and will still add more information that is currently lacking once our composition results are due. During the technical committee meeting, it was evident that data on composition of our local propolis was limited and even setting limits was difficult because of unknown levels of contamination. The findings of laboratory analyses from this project will be able to give a Ugandan position on the standards."*

The above quotation from a project participant highlights the type of impact research can have on policy processes.

A policy brief has been drafted to support TUNADO (the governing body for beekeepers) to lobby how issues raised in the exploitation of these new products shall be handled. Findings of composition analyses once ready shall be submitted to the Uganda National Bureau of Statistics (UNBS) to support standards development.

> *"The training manual for propolis and bee venom handling under the African context being developed will be the first in East Africa that may be also adopted by neighbouring countries."*

In case study 4, the project team in the course of the project implementation made a presentation at a Cleaner Cooking Camp through the National Cook Stove Steering Committee which is chaired by the Department of Energy Affairs. The policy brief has been developed and shared with the parliamentary committee on environment, department of forestry, department of energy, department of environment and the overall Ministry of Energy, Natural Resources and Mining. The policy brief has also been shared with the Malawi Energy Regulatory Authority (MERA) to inform the development of a regulatory framework for biogas systems in Malawi.

Organizational culture and practices

Private and public-sector organizations have cultures and practices that are at times conflicting and this sometimes becomes a challenge. For example, the private sector expects to be paid immediately upon supplying an item; however, in a public institution these items need to be verified by the auditor before payments are approved. Sometimes private actors share information without team approval thereby jeopardizing the privacy and procedures of the project, and in some cases threatening the intellectual property protection of the products.

For monitoring and traceability, record keeping has improved and institutions such as SVAR-RTC has a registry (book) where all new persons contacting the project for help in propolis product development are registered. For example, available records show that since the press release, three persons have called for help. One wanted to add propolis to cosmetics, another farmer wanted to see how to add propolis into his ice cream and there was someone who just wanted supply of bee venom.

On governance, the projects have adopted attendance forms that are signed to capture details of the engagement. Some of the projects have also signed agreements for engagement, and each stakeholder assigned activities to implement and budget, and resources accordingly allocated. These are important in reducing conflicts and managing any such conflicts wherever they occur.

> In case study 4, the system was designed by Intrinsic Biogas Company and the bill of quantities shared with the project team. The model is that GIT will take over the plant once all is done to operate it for sustainability. The technology being used on this project is a patented design by the contractor – Intrinsic Biogas Company. This is a cross flow biogas system with up to three stages digestion system within one digester. The design was selected based on the time needed for the substrate to be digested and the retention period. The design also incorporates the greenhouse system which will increase heat as the selected area has low temperatures during the winter. The project is being implemented in an area where agri-business is increasing, hence an inclusion of liquid and granule bio-fertilizer to assist farmers to increase the crop yield and improve soil fertility.

Lessons and prospects for the future

New products and technologies

The new technologies and products developed under the PPP projects are a testimony of the viability of this approach in facilitating and fostering technology transfer and knowledge exchange between different actors within the national innovation ecosystem. All the five projects in Malawi and Uganda have resulted in some novel products that have been prototyped and tested. Some of these, such as the propolis powder have not been exploited as a commercial product in Uganda and the idea of incorporating the propolis powder into juice is new in the Ugandan market. These products are anticipated to grow commercially.

The confectionary products under the maize germ and bran products have not only introduced more nutritious products in the market but also expanded the product portfolio at the private sector partner

business lines. This increases revenue and conversion of what would have been waste products into new income streams.

In Malawi's renewable energy sector, the introduction of the biogas system to deal with health and sanitation at the Tsangano market under the fee-for-service model offers opportunities for an academia-private sector-community partnership that is likely to offer long-term solutions to deforestation, soil degradation and sanitation.

New business opportunities

The private sector is getting excited about the business prospects of the new products and processes such as propolis, maize germ and bran in human food and the fermentation box. For example, when private actors read in the papers that the bee propolis project was buying propolis to make powder, this resulted in increased competition for the raw material; consequently prices rose from Ush 15,000 per kg of raw material to Ush 30,000 per kg.

The biogas project is the first of its kind in Malawi and it is being piloted when the country is facing massive deforestation owing to high demand for firewood and charcoal for cooking. The project positions MUST as a leader in research on renewable energy and agricultural activities. At the policy level, the project has attracted interest from the Department of Energy Affairs and Malawi Energy Regulatory Authority who are keen to learn from and design future projects adapting the concept piloted at Tsangano market.

Similarly, the solar-powered milking machines in Malawi's dairy industry have attracted the interest of the cooperatives who have committed to collect funds and upscale the uptake and use of such machines among their members. This has already expanded business opportunities for the private sector partner – OIWS – in selling and maintaining these machines.

New uses for locally available raw materials

In all the cases, the use of what would have been considered waste products or by-products have now been put to productive and beneficial use through the projects. In some cases, such as the maize germ and bran, customer perception and attitudes will require further sensitization or careful product labelling to change people's mindset regarding maize bran and germ as animal feed.

In the biogas case in Malawi, the incorporation of a public toilet facility and an abattoir into the raw materials for the project after an

agreement with the municipal council is a pointer to the usefulness of what would have been abandoned projects. In the dairy project, farmers have donated their facilities and resources including land, labour and other inputs in the spirit of partnerships and collaboration. For sustainability, they have committed their own financial contributions from their cooperative savings besides other in-kind contributions.

Notes

[1] Most countries have forward-looking development blueprints, e.g. the Vision 2030 in Kenya. Almost all of these are anchored on science, technology and innovation (STI).

[2] That now place emphasis on multi-disciplinary, multi-institutional collaborations and demonstrated partnerships with the private sector (STI grants scheme).

[3] Examples such as LIWA (Linking Industry with Academia) in Kenya could be found elsewhere in the study countries.

[4] These case studies are derived from (i) public-private partnership (PPP) projects under Phase 1 of the Science Granting Councils Initiative (SGCI) in Uganda and Malawi.

[5] For details on this project, see policy brief: "*Maize germ and bran for value addition: high fiber bakery and confectionery products*" available at: https://scinnovent.org/wp-content/uploads/2020/02/Policy-Brief-08-for-print.pdf

[6] For details on this project, see policy brief: *"Strategies for increased utilisation of new propolis products in Uganda*" available at: https://scinnovent.org/wp-content/uploads/2020/02/Policy-Brief-11-for-print.pdf

[7] For details on this project, see Policy brief, *"Building the capacity of small-scale cocoa farmers to conduct on-farm fermentation* available at: https://scinnovent.org/wp-content/uploads/2020/02/Policy-Brief-04-for-print.pdf

[8] For details on this project, see policy brief, *"solar powered technologies for the smallholder dairy industry in Malawi*" available at: https://scinnovent.org/wp-content/uploads/2020/02/Policy-Brief-06-for-print.pdf

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