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Concept paper

Enhancing food safety through adoption of long-term technical advisory, financial and storage support services in maize growing areas of east Africa

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Abstract: Grain production and storage are major components in food security. In the ancient times, food security was achieved through gathering of fruits, grains, herbs, tubers, and roots from the forests by individual households. Advancements in human civilization led to domestication of crops and a need to save food for not only a household, but the nation. This extended need for food security led to establishment of national reservoirs for major produces and this practice varies greatly in different states. Each of the applied food production, handling and storage approaches has got its benefits and challenges. In sub-Saharan Africa, several countries have a public funded budget to subsidize production costs, to buy grains from farmers and to store the produce for a specific period and/or until the next harvests. During the times of famine, the stored grains are later given free to the citizens. If there is no famine, the grain is sold to retailers and/or processors (e.g., millers) who later sell it to the consumers. This approach works well if the produce (mainly grain) is stored under conditions that do not favor growth of molds, as some of these could contaminate the grain with toxic and carcinogenic metabolites called mycotoxins. Conditions that alleviate contamination of grains are required during production, handling and storage. Most of the grain is produced by smallholder farmers under sub-optimal conditions, which make vulnerable to colonization and contamination by toxigenic fungi. Further, the grain is stored in silos at large masses, where it is hard to monitor the conditions at different points of these facilities, and hence it becomes vulnerable to additional contamination. Production and storage of grain under conditions that favor mycotoxins poses major food health and safety risks to humans and livestock who consume the grain. This concept paper focuses on how establishment of local grain production and banking system (LGPBS) could enhance food security and safety in East Africa. The concept of LGPBS provides an extension of advisory and finance support within warehouse receipting system to enhance grain production under optimal conditions. The major practices at the LGPBS, and how each could contribute to food security and safety are discussed. While the concept paper gives more strength on maize production and safety, similar practices could be applied to enhance safety of other grains in the same LGPBS.

Keywords: Maize; Food Safety; Community-based Support systems; Integrated Mycotoxin Control Strategies

1. Introduction

Maize is a staple food to the east African people and is consumed at a per capita rate of slightly above 90 kg /year in the region [1]. Because of the dietary value attached to maize in Kenya and Tanzania, a lack of maize is synonymous to a "famine hit". To cushion the consumers against famine, the governments provide subsidized fertilizers and buy maize grains and store them at national strategic grain reserves, which are located at the major producing regions [2-4]. The quality and quantity of the produce stored in the strategic reserve depends on farm management and the immediate post-harvest handling techniques [5]. Cultivation of maize under stress induced by abiotic or biotic conditions can lead to low yield and poor quality grain. Furthermore, inadequate application of farm inputs would affect the quality and quantity of the grain [6]. In East Africa, the majority of maize is produced by small-scale farmers under sub-optimal farm conditions [2,7,8]. Maize that is produced under drought and under low nitrogen was reported to have high chances of contamination by mycotoxins, toxic and carcinogenic substances produced by some grain molds [9,10]. To enhance the quality of harvested maize, there is need to adopt strategies that can enable farmers to produce the crop under the optimal conditions.

Although different countries have tried to subsidize fertilizer, other maize stress factors such as drought, weeds, pests and diseases, and post-harvest handling methods affect the quality of the grain [10,11]. Additional deterioration in grain quality occurs when the produce is stored under conditions that favor the growth of toxigenic molds and toxin production [12]. To ensure safe storage in the strategic reserve is of good quality, workers of the reserve facility conduct grain moisture content tests upon delivery of the grain by the farmers. If maize has moisture of above 13%, the farmers are required to dry the grain to the recommended content, mainly by pouring and spreading it on the surface of plain polythene sheets which are placed on the ground under the sun [13]. Once dried, the grain is repackaged into gunny bags and reweighed before it is purchased for storage within the facility. The number of bags stored within a facility depends on the annual government budget and the availability of the commodity in the respective regions during the specific season. The storage facilities consist of huge silos where the gunny bags are kept in large masses. These bags are stored for 4-12 months. In Kenya, massive mycotoxin contamination has been reported in farmers' storage sheds and the national maize reserves [14]. Application of better grain handling and storage methods can reduce loss of maize quality and mycotoxin contamination [15].

Availability of food does not fully address the food security concerns if the food is unsafe and/or is contaminated. While Africa struggles to boost its food production to feed the burgeoning population, food safety challenges arise from several environmental contaminants such as industrial wastes, sewage systems, plant toxins, food additives, pesticide residues and mycotoxins. Mycotoxins contamination within a food chain occurs before harvest and is exacerbated when the produce is improperly handled or stored [15]. Mycotoxins contribute to the huge burden of food contaminants across the world, and pose a particularly large health risk to maize consumers in east Africa [14,16]. The chronic risk factor for mycotoxins is higher than for any of the other contaminants [17]. There is an increasing concern that extreme conditions due to climate change could worsen food safety in Africa [18]. Efforts to mitigate mycotoxins, particularly aflatoxin contamination in east African maize, have recently gained momentum, but there is still need for more action. Given the complexity of the problem, there is need to adopt concerted approaches to effectively prevent factors that favor contamination in the entire maize value chain (Fig. 1).

Mycotoxins of importance in East African maize value chain include aflatoxin and fumonisin [16,19,20]. Aflatoxin is mainly produced by *Aspergillus flavus,* a maize pathogen which causes ear rot, and by *A. nomius* and *A. parasiticus* [21]. Aflatoxin B1 is the most potent carcinogen known globally, and has been reported to contaminate maize and peanuts in many parts of eastern and central Africa [22]. The factors for and the effects of the toxin are described below, as it represents a classical case for the complexity of mycotoxin contamination in maize value chain (Fig. 1). Acute exposure to aflatoxin routinely causes lethal poisoning, including a recent outbreaks in Kenya and Tanzania [23,24]. Chronic exposure to aflatoxin has been associated with multiple health issues such as liver cancer, stunting of children, immunosuppression, and poor fetal development [25,26]. The crop is also vulnerable to colonization and contamination by Fusarium fungal species which produce fumonisin, a carcinogen of the esophagus which is widespread in maize growing areas of east Africa, particularly Tanzania and Kenya [16,20,27].

The ideal strategies to effectively manage aflatoxin and fumonisin contamination would be to prevent plant stress during crop production in the field, ensure proper handling during harvesting, and to store the grain under conditions that do not favor growth and contamination by the toxigenic molds. Unfortunately, such ideal conditions are not easy to achieve by all stakeholders in the value chain. The majority of the small-scale holders are faced with challenges of meeting the high costs of maize production inputs. Further, farmers may not have the capacity to grow and handle the grain under conditions that prevent peri-and post-harvest contamination [28]. Although the majority of the small-scale grain traders sort or blend to reduce the concentration of apparent moldiness in the purchased grain, this practice has not been proven to significantly reduce aflatoxin, but fumonisin [16]. Additionally, if the grain is sold to traders at a high moisture content, the level of contamination could increase during storage in a wait for the sale to the millers and the grain reserve. In Kenya and Tanzania, it is obvious for farmers and traders to spend weeks in a queue of trucks for the grain to be offloaded at the millers and at the grain reserves. This delay in offloading of trucks could be a terrible cause of deterioration and mycotoxin contamination in grain that might have been harvested at a moisture content above 13%. Upon delivery at the storage silos, grain that is already colonized by toxigenic molds is likely to have more contamination, if the conditions are not checked.

In the current setting, the East African national grain reserves serve the storage purpose. However, establishment of facilities that can tackle other factors affecting maize value chain, alongside the storage and safety concerns still is prudent. For the theme of enhancing maize productivity and safety, there is need to establish sustainable systems that not only address soil fertility and grain storage, but also can minimize other risks for mycotoxin contamination at pre-, peri and post-harvest stages. To deal with the challenges arising from the NCPB, Kenya has passed a policy to create a warehouse receipt system (WRS) for grains [29]. The WRS allows farmers or traders to deposit their grain at a nearby certified warehouse facility and then be issued with a document of title called a warehouse receipt. The farmer or trader can then apply for short-term credit from a participating bank or other financial institution using the warehouse receipt as security for a loan, thus increasing access to finance for small-scale farmers [30]. While this is a good idea, the design implies that the credit accessed would differ based on the income of the farmer or trader. However, because harvested grain is consumed by the whole community and country, at large, there is need to expand this system to ensure that farmers are given sufficient support to produce to the capacity of their farms. Here, we propose a concept of a community-supported farming system, to exist as an expansion of the WRS through provision of financial credit and crop management advisory system at different stages in the value chain. It is envisaged that implantation of the concept can boost maize production, productivity, and profitability, and to effectively reduce contamination and human exposure to the damaging toxins.

2. The concept of local grain production and banking system (LGPBS)

2.1. Description of LGPBS

Conceptually, LGPBS refers to centers that provide farm inputs, management practice advisory services, grain aggregation, grain storage, grain drying, grain safety assessment and credit facilities to farmers in the neighborhoods where the grains are grown. These centers could be established through collaborations between corporate organizations, local, and/or national governments. The centers could operate within delineated maize growing areas which could be termed as maize production schemes. The sizes of the schemes and capacity of the centers would depend on the intensity of grain production within a given scheme. However, each individual center should be able to efficiently provide key support service to the farmers within the respective schemes. LGPBS would ensure that the grain is produced under optimal conditions by providing advice and inputs to farmers to ensure that the crop has minimal stress. They would further participate in provision of facilities which ensure that the harvested grain is appropriately handled and tested prior to storage under the custody of the WRS. Because the centers serve many farmers in a given schemes, they would participate in finding potential grain buyers, and in turn, farmers would deposit the grain. Per the WRS program, farmers can withdraw their grain on regular basis and can even acquire credit depending on the value of their contribution in the center [30]. Owing to the economies of scale enjoyed by bringing the farmers together, the LGPBS would play a key role in enhancing better livelihoods of the participant farmers. They would serve as key points through which any interested governmental and non-governmental organizations can channel their support for the farmers in the region. The sustainability of the centers would be through the business transactions with the farmers and external resource mobilization e.g., support by local and national governments, development partners, and donors.

Major stakeholders of the LGPBS would comprise the farmers, ministries of agriculture, agricultural research institutions, health and water organizations from local and national governments, private investors, agro-dealers, seed companies, national food safety organization, microfinance organizations and insurance companies. Each of these bodies would contribute at different points in the grain value chain (Fig. 2). Although the government agencies would have a stake, a preferred model to have LGPBS operate as independent businesses with autonomous management. The autonomous management would enhance efficiency by eradication of bureaucracy and political interference, and hence better service delivery to the farmers. The key sections of the LGPBS would work in tandem to ensure that all major services are efficiently provided to the farmers, with an overall goal of enhancing increased maize productivity and safety within the respective production schemes.

2.2. Role of LGPBS in management of mycotoxins

The scope of the current paper will be limited to activities that directly relate to eradication of mycotoxin contamination. It is proposed that these centers be key points for control of mycotoxins because the problem needs to be tackled at different points in maize value chain [31,32]. Although many agencies have proposed many great ideas to tackle mycotoxin contamination in maize, no single action can individually solve the complex problem, as it involves different points in the maize value chain (Fig. 1&2). It is envisaged that adoption of these local grain support centers will not only overcome the pre-harvest production constraints, but also replace the currently applied storage systems which can easily allow for colonization of maize grain by toxigenic fungal species (Fig. 3). Further, the localized systems could be designed to overcome the challenges faced with the heaping of grain in large silos at the national reserves, through adoption of modern facilities which provide for better grain drying and aeration (Fig. 4). By establishing a facility with different support systems to enhance maize production, the potential mycotoxin mitigation strategies are brought together and the efforts can complement in tackling the challenges at different levels in the value chain (Fig. 2). The key sections of the center are expected to interact amongst themselves and with the stakeholders as illustrated herein (Table 1&Fig. 5).

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Fig. 1. A problem tree of the aflatoxin contamination in maize

Table 1. Support services and activities to enhance production of safe maize grain in east Africa.

Point in the value chain	Activity/support	Aspect in the aflatoxin problem tree	Sections of LGHBC
Pre-harvest	Provision of certified seed of cultivars with desirable traits	Less **susceptible maize genotype**	-Agronomy advisory team – this would provide farmers with the appropriate information on the best cultivars to grow -Finance credit – this would provide information on monetary support to enhance acquisition of the seed
	Provision of farm labor	Improved **soil** quality	-Agronomy advisory team – inform farmers on the correct tillage method, based on the type of soils in their farms -Finance credit – enhance payment for tillage labor
	Input for control of soilborne pests/weeds/other pests and diseases	Improved **soil/plant health**	-Crop Protection section – to provide appropriate information on what pesticides and/herbicides, and the appropriate timing and rates for application. -Finance credit- to enhance acquisition of the appropriate input
	Fertilizer application	Improve **soil nutrient content**	-Agronomy advisory team – this would provide appropriate information on fertilizer type, rates and timing for application, based on farmer's field conditions -Finance credit – facilitate purchase of fertilizer
	Provision of information on plant spacing	Reduced competition and enhanced **plant vigor**	-Agronomy advisory team – this would provide the advice to the farmers based on the type of cultivar they grow in their fields
	Water provision to the crop	Management of **water stress**	-Water Harvesting Section – this would support farmers to ensure that the crop gets optimal amount of water -Finance credit- to support water harvesting initiative for the farmers
Peri-harvest	Information on proper harvesting equipment	**Good harvesting practices**	-Agricultural Mechanization team – provide appropriate information on the most sustainable harvesting methods. Could adopt harvesting using special equipment which is provided by the LGPBS
	Information on shelling devoid of kernel breakages	**Good harvesting practices**	- Agricultural Mechanization team – provide appropriate information on the most sustainable harvesting methods.
Post-harvest	Information on the appropriate grain packaging equipment	**Grain handling after harvest**	-Postharvest Loss Prevention team – can advise the farmers on how to package the grain. If possible, the LGPBS should take the responsibility of packaging in bags that can allow sufficient grain drying prior to storage -Finance Credit – they could lend money to the farmers to buy the appropriate storage equipment.
	Proper collection of grain for delivery to LGPBS shelves	**Grain handling after harvest**	Postharvest Loss Prevention and Transport sections of the LGPBS to facilitate delivery of the grain to the local reservoir. This should avoid exposure to additional moisture
	Provision of grain drying services by the LGPBS	**Drying** to attain optimal grain storage moisture	-Postharvest Loss Prevention team – the LGPBS should have sustainable /inexpensive grain drying methods. To reduce the cost of running the system, modern solar powered driers could be acquired and utilized. They would provide information to farmers about maize cultivars with fast kernel dry-down
	Prevention of damage by storage pests	**Control of weevil** and other storage pests	Postharvest Loss Prevention team – grain could be stored at conditions that do not favor infestation by weevil, moths and rodents. The section could apply recommended pesticides to keep the grain free from damage

2.2.1. Advice on farm practices

Farmers' advisory services is a key component in grain production. While this service is a duty of the agricultural extension agents, the specific design of the LGPBS can determine whether these important government workers could take duties within these centers. To provide specific advice to farmers, the centers would involve qualified and experienced personnel on need basis. The services would include how to conduct pre-, peri and post-harvest management practices. This would ensure that the crop is produced under optimal conditions.

2.2.1. a) Good agronomic practices

Proper farm management practices can boost crop vigor and are able to reduce crop stress and the subsequent susceptibility of maize to mycotoxigenic fungi [33]. Crop stress is determined by multiple factors during the growth and development stage. For example, aflatoxin accumulation in maize has been strongly associated with drought, insect damage and a lack of adequate nitrogen in the soil [9,12,13,34]. The LGPBS centers can play a role of advising farmers on how to adopt sustainable methods to ensure that the crop is produced without water, soil fertility and biotic stresses, as these would lead to mycotoxin accumulation. Individual stress factors can be managed by adoption of the strategies on case basis.

Management of soil environment and fertility: good soil architecture, aeration and fertility are components for the maize growing agro-ecologies. Thus, characterization of the physical and chemical aspects of the soil is an important activity prior to a recommendation for crop establishment [35]. While farmers in East Africa have a tradition of growing what they have seen in other farms at the neighborhood, it is imperative that governments should zone crop production activities based on evidence of the prevailing favorable soil conditions for maize production. Certain cropping systems, tillage methods and application of natural and synthetic fertilizers could be used to adjust and attain the appropriate architecture, but proper expertise advice is necessary [16,35-37]. The LGPBS can play the role of providing advice through which various soil conditions can be overcome to achieve the requirements of maize production. To achieve this, the LGPBS should have established soil analytical capabilities. The LGPBS could also offer advice on the recommended fertilizer application rates to the farmers. Currently, soil testing services are limited to very few institutions which are located within the major cities of east Africa. Good soil health would translate into better utilization of nutrients by the crop, hence a higher vigor and less susceptibility to mycotoxin accumulation [9,38].

Management of weeds, pests and diseases: biotic stresses are parasitic to the crop plants. Weeds compete for water and nutrients or they could attach themselves and deprive the nutrients (e.g., *Striga hermonthica*.) causing up to 85% loss in maize crop [39,40]. Stress due to weed infestation has been strongly associated with aflatoxin and fumonisin contamination in maize [41,42]. Thus, the center can play a key role in advising farmers on accurate timing and rates of application of herbicides, and/or the manual management of the weeds. Insect pests cause damage to field and stored crops. The parasitic field pests deprive maize of the nutrients and water, and their feeding creates infection courts for toxigenic fungal species. Damage of maize by thrips was strongly associated with fumonisin accumulation [43]. Further infestation on mature grain causes breakage and avenues for penetration and colonization by molds, and hence contamination by aflatoxin [16]. Application of insecticides reduces insect damage, and hence enhancing crop vigor. Furthermore, application of fungicides eradicates both true and opportunistic fungal pathogens, some of which are mycotoxigenic. Because the majority of farmers may not know about the proper application of chemicals, there is need for the LGPBS to have expertise who can provide advisory services. The facilities could also be used as points of distribution of products with beneficial microbial organisms to the farms (e.g., the biocontrol products currently being adopted in different countries in Africa) [44].

Water stress management: although there is a lot of climatic data that has been gathered over the years, there is a concern that climate change will bring uncertainty in crop production and food safety. Erratic weather conditions can lead to unexpected drought and floods within the arable regions of east Africa. The magnitude of drought determines whether a certain season would provide any grain to the farmers. Under extreme conditions, there is little or no grain, and the little that is available could be contaminated with aflatoxin [34,43]. In this situation, maize consumers eat what is available, and are likely to be exposed to the damaging toxins. Proper mapping and communication of drought risk to farmers could prevent exposure to damaging toxins. The LGPBS could work with the meteorological departments to provide timely awareness about the weather changes in given locations, and the best crop cultivars/varieties that suits the contemporary seasons. The LGPBS could also provide advice on cropping systems that could conserve moisture and facilitate water harvesting. As a long term intervention, the centers could work with government agencies to establish inexpensive water harvesting strategies for their schemes.

Provision and promotion of seed stocks of adapted maize cultivars: While each of the identified practices for reduction of mycotoxin accumulation through agronomic practices only confer a fraction of the overall effect, identification of an adapted cultivar for individual maize production environments can be important in solving the problem. Adapted maize cultivars possess a cumulative resistance owing to multiple important traits that protect them against the mycotoxin predisposing factors [45]. Although genetic resistance to aflatoxin and fumonisin has not yet been bred into east African maize, the problem can be overcome by growing adapted maize cultivars as they possess some of the key traits that are associated with reduced contamination [9,46]. Thus, the LGPBS could advise the farmers to grow maize cultivars that are well-adapted to the abiotic and biotic stresses of a given environment [47]. The LGPBS can have a stock of the seed of the adapted and good performing maize cultivars for provision to farmers during the planting season. Among the traits that have been associated reduced mycotoxin accumulation in maize are: maturity, tolerances to drought, insect damage, low soil nitrogen, and compactness of the endorsperm (flintness) [9,47,48]. As a long term intervention strategy, breeders could work with the LGPBS to identify key germplasm for integration of the traits which are correlated with mycotoxin resistance into high adapted and yielding backgrounds using modern breeding methods such as genomic selection [49].

2.2.1. b) Timely and proper management of agronomic practices

The majority of the farmers pay for farm labor. In some cases, the farm activities may not be accomplished to the right standards due to lack of sufficient training of the workers. To overcome the bottlenecks of unskilled labor, LGPBS could establish a pool of trained workers to perform some farm practices for at a fee. The crew would ensure that the major farm activities are performed correctly and within the acceptable timing. For example, timely planting is essential for rain-fed maize because the crop gets the advantage of early establishment, before the onset of other biotic stresses and competitors, and could reduce plant stress and aflatoxin accumulation in maize [50]. Timely control of weeds is essential because it prevents detrimental competition with the crops (Fig. 2). Also, pests and diseases must be controlled early enough to avoid epidemics which can lead to extreme plant stress, quality damage and economic losses [28,51]. Timely harvesting ensures that the activity does not take place when it is rainy, the ears are not over matured, and the kernels have not been broken by weevil, as these would lead to further entry of the toxigenic molds (Fig. 2) [13].

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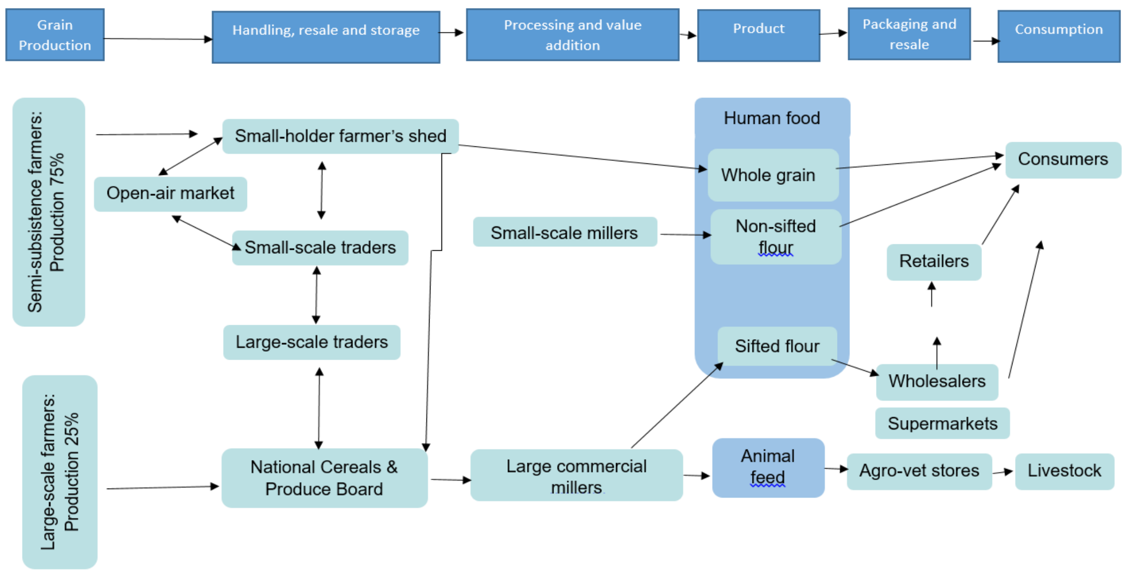

Fig. 2. A schematic summary of the east African maize value chain showing the importance of small-scale growers. The small-scale growers are faced with multiple production constraints, which could be solved by adoption of the local grain handling and banking centers.

The alternative to offering labor for the farmers is to provide advice and training for better pre-, peri-and post-harvest farm practices. Further, the facilities should provide information about the available products, services and opportunities throughout the maize value chain. To achieve this, the centers would prepare teaching materials and hold regular training workshops. Regular farm visits to farmers fields by trained personnel is required to ensure proper implementation of the farm practices. In a case where records are given to the farmers, the trainers must ensure that the best possible methods of communication are applied (e.g., the majority of the farmers are not able to understand the fertilizer and pesticide application rates). Thus, the experts need to know the exact size and the planting density in their farms so that they can recommend the optimum amounts of inputs to be applied in the entire field.

2.2.1. c) Harvesting and post-harvest practices

Peri-harvest activities can play a key role in preventing mycotoxin contamination. For small-scale farmers, harvesting involves cutting off the maize plants and stacking them to remain in the field for several days and/or until they are presumed to be dry [52]. Field stacking does not provide sufficient aeration for the ears, and could lead to colonization of grain my toxigenic molds. Upon drying, maize is dehusked and dropped onto the ground to dry up and then they are collected into some bags ready for transport. Dropping of de-husked ears on the ground can expose maize to entry of the spores of toxigenic fungi [53]. Through on-farm demonstrations, LGPBS would serve the role of providing advice on how to handle the maize ears appropriately during harvesting. The LGPBS would provide inexpensive moisture testing equipment at a fee. The facility could also acquire and install multiple modern driers (e.g., EasyDry M500) so that farmers can deliver the grain for a centralized drying [54]. Further, the centers could also provide seeds of maize with fast dry-down. The combined approaches would reduce the grain drying duration. Fast drying would reduce chances of entry of toxigenic fungi and hence preventing mycotoxin contamination.

Grain shelling should be conducted in a way that minimizes kernel breakage, as these have been associated with increased mycotoxin contamination [16]. The majority of small-scale farmers shell maize using mechanical methods that can cause breakage. To avoid this problem, the LGPBS could establish inexpensive and high throughput mobile on-farm shelling equipment, which could be shared by farmers within the scheme. To ensure that only clean ears are shelled, farmers would be advised to sort and remove ears with apparent moldiness. Removal of moldy ears after harvest was found to significantly reduce aflatoxin contamination in maize [15]. Sorting based on apparent moldiness was also found to reduce the percentage of contaminated samples by more than half [16].

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To advance the safety through more efficient sorting, the LGPBS could work with scientists to validate and adopt multi-spectral sorters, as preliminary studies have shown that they can detect and sort both aflatoxin and fumonisin [55].

A B C

Fig. 3. Mycotoxin predisposing maize handling techniques by small-holder farmers of Bungoma, Kenya. A. Maize ears are dropped on the ground during harvesting. B. Maize ears are dried on the ground. C. Maize ears are stored in traditional wooden cribs which are vulnerable to entry of water and rodents. Photos were taken by Samuel Mutiga during a mycotoxin survey in 2010

Upon drying, the grain can be packaged in aerated bags which can handle a mass that can be easily handled by human operators (e.g., a maximum of 25 kilograms). The grain can then be transferred to the LGPBS facility for storage. To prevent entry of weevil during storage, regular inspection and fumigation with insecticide should be conducted. To avoid challenges associated with the traditional grain storage systems, the WRS should provide storage systems which includes modern facilities (Figs. 3). If not prevented, weevil can cause breakage and could introduce opportunistic molds to the stored grain. Recently, there have been many reports of successful hermetic grain storage technologies for to prevent weevil damage and subsequent accumulation of mycotoxins. For example, the hermetic plastic and metallic silos, Purdue Improved Crop Storage (PICS) and GrainSafe® bags have been widely recommended for storage of maize and other grains [56]. The LGPBS can evaluate the potential of storage of maize in these improved facilities or adopt the same technologies in larger equipment to accommodate the large volumes of grain from their schemes.

2.2.1. d) Innovations for decontamination and alternative use of contaminated maize:

It is anticipated that LGPBS will consult and work with experts at different stages of grain value chains to ensure maximum quality and safety of the produce. One important area of support that would contribute to food safety is research on new technologies. By working with local and international research organizations, these centers can test existing and new technologies. For example, although some interventions were found to reduce mycotoxin contamination at experimental level, they have not been tested in actual field conditions. A promising technology like spectral sorting has been reported to work in the developing countries, and was recently tested at laboratory level in Kenya [55]. Additionally, a recent study showed a less aflatoxin in maize kernels of low density, but the potential of density-based sorters has not received adequate support to enhance evaluation [9]. Similarly, addition of diatomaceous earth has been reported to enhance grain drying and to reduce weevil infestation, but this technology has not received enough scientific support to ensure its safety and efficacy in East Africa [57,58]. The facility could also serve as a learning and acquisition center for foreign food preparation practices such as nixtamalization (washing and cooking of maize in an alkaline solution), as this reduces aflatoxin levels [59]. The facilities could also be used as centers for application of alternative uses of contaminated maize. For example, after sorting, the highly contaminated grains could be used to generate heat energy. The facilities could explore possibilities of utilizing the contaminated grain for production of ethanol. Ethanol production from maize is common in the US [60].

2.2.2. Farm input provision and related services

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The small-scale farmers of East Africa are faced with financial challenges and may not afford some important farm inputs e.g., fertilizers, herbicides, pesticides [61]. To boost farmers' productivity, provision of inputs on need basis can be helpful. For most regions of east Africa, input provision are incentives provided by the governments or by donors agencies [61]. However, these interventions are not sustainable and are faced with inefficiencies due to lack of resources and a general misunderstanding of the requirements for different growing parts of individual countries. To bridge the gap of the lack of actual demands of specific agro-ecologies, the LGPBS would be able to assess the needs and react to farmers in each of the grain producing areas. Timely provision of herbicides would reduce competition between the crop and weeds, and hence boosting crop vigor. Additionally, timely provision of pesticides would ensure that insect pests and diseases are managed before they can achieve economic threshold. The most promising role of the LGPBS would be to stock the inputs and to provide them, together with support services (e.g., advice and labor) to avert plant stress. These incentives would be achieved in a business agreement between the local facility and the farmers. In addition, farmers would benefit from advice on how to apply the inputs appropriately.

2.2.3. Sales, promotions and credit services

LGPBS would be major stakeholders in grain production and would play a role in establishing better external markets for the farmers. This means that they would advertise and promote the grains (and any associated products) from their respective regions. In return, LGPBS would benefit from sales commissions. Furthermore, LGPBS could benefit from interests arising from grain banking systems. On the other hand, farmers would benefit through timely access to advice, inputs and loan services, better quality grain and reduced exposure to mycotoxins. Individual centers would develop and market their products to the farmers and to other customers outside their geographical areas.

2.2.4. Grain custodians and the associated banking services

LGPBS would aggregate and store grain on-behalf of the farmers in a model named warehousing receipt system [30]. Establishment of the WRS was aimed at banking systems for the grain and would replace the current storage systems which are characterized by large storage silos (Fig. 4).

Figure 4. Maize drying, packaging and storage at the national cereals and produce board of Kenya (source: https://www.nation.co.ke/oped/opinion/africa-economy-growth-government-development-youth/. Similar storage structures exist at The Tanzanian National Reserve Food Agency.

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To obtain the custody, the center would develop a system of tracking the transactions for individual farmers, as described by the regulations of individual countries. In the current concept, additional key activities have been described to be implemented at the LGPBS besides grain banking. As a custodian of large quantities of grain from the many farmers, the LGPBS facility would enjoy economies of scale and hence they can build modern equipment to handle the grain appropriately. As a food safety enhancement measure, grain banking by the LGPBS would ensure that the important produce is not kept under conditions that would favor mycotoxigenic fungi. It would also ensure that the grain is handled by personnel who have a better understanding of the conditions that lead to contamination. Furthermore, because LGPBS are business oriented, there would be a greater sense of responsibility and hence regular monitoring of the quality would be implemented in the facility. The potential benefits of the proposed LGPBS are summarized (Fig. 5).

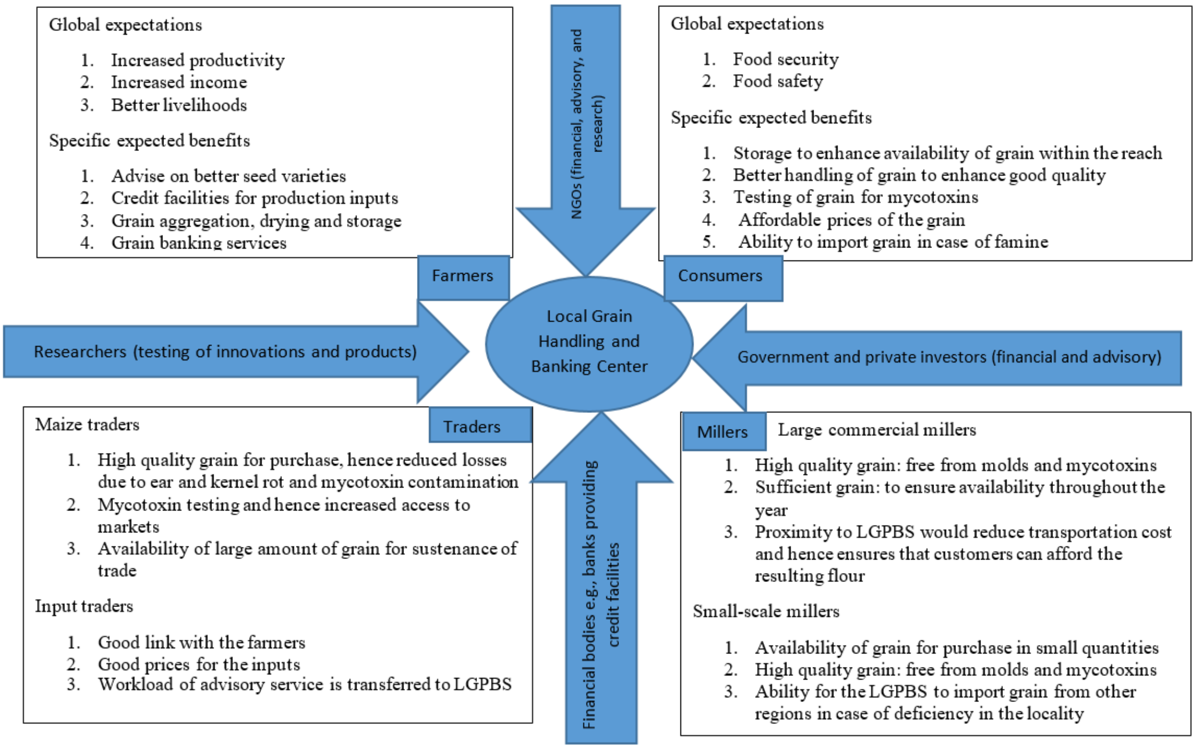

Fig. 5. Concept model of how LGPBS would be implemented to enhance maize production and safety to consumers in East Africa.

3. Conclusions

The complex problem of mycotoxin contamination in maize has been a major challenge in enhancing food safety and security in east Africa. Here, we have put a concept through which the grain production, handling and storage practices could be improved by establishment of the local grain production and banking systems. The concept of LGPBS provides an opportunity to stem the problem of quality loss of grain at all stages of the maize grain value chain. Establishment and operationalization of the facilities would ensure that stakeholders are cushioned of losses associated with maize quality and quantity losses caused by abiotic and biotic constraints. Further, the facilities would provide an environment where farmers who are willing to venture into maize agri-business are fully supported through provision of inputs, finance and advisory services. This would in turn lead to production of maize under optimal conditions, and hence reduced mycotoxin contamination, and a subsequent reduced exposure of humans and livestock to the damaging toxins. Furthermore, the post-harvest handling and storage systems would ensure that there is minimal or no grain loss due to rot and mycotoxin contamination. This facility, if adopted would not only lead to enhanced grain productivity but also improved food safety. An increase in grain production would enhance trade and better livelihoods. On the other hand, enhanced food safety would lead to a more health population. Therefore, LGPBS provides an excellent concept towards enabling agribusiness, safety and food security in east Africa and beyond.

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