A multi-stakeholder approach to mitigate aflatoxin contamination of food and feed

Contents

1. Introduction 1

2. Possible interventions along the value chain 2

2.1. Testing for mycotoxins 3

2.2. Raising awareness of all actors through education, information and knowledge sharing 3

2.3. Good pre-harvest agricultural practices 5

2.4. Good postharvest practices 7

2.5. Good Manufacturing Practices 8

2.6. Decontamination 9

2.7. Integrative PPPP (Public Private Producer Partnership) 9

1. Introduction

PAEPARD is organising with the Directorate General Sante of the European Commission and the East African Farmer Federation (EAFF), and in collaboration with the Partnership for Aflatoxin Control in Africa (PACA) and the African Society of Mycotoxicology (ASM), a roundtable meeting of key aflatoxin experts (not only research experts) on the mitigation of aflatoxin in food and feed in Africa on Monday 25th January 2015 in Brussels (by invitation only). This is a follow up to the PAEPARD policy brief on the aflatoxin contamination of food and feed in Africa presented during the DEVCo Info Lunch conference in Brussels on 26th October 2015.

This note is to guide the presentations in the afternoon of 25/01 and the possible creation of consortia around future funding opportunities related to: (a) Raising awareness ; (b) pre-harvest postharvest and manufacturing agricultural practices ; (c) decontamination

2. Possible interventions along the value chain

Overall, there should be incentive/motivation mechanism especially for small scale farmers if significant impact is expected. So, there is urgent need for having incentive/motivation mechanism along with technology dissemination. (Dr. Benoit Gnonlonfin, INRAB)

The **1st Symposium on African Mycotoxicology** (Zambia, May 2015) suggested addressing the mycotoxin problem in Africa by:

- Raising awareness of all actors through education, information and knowledge sharing;
- Adopting good agronomic practices such as early harvesting, use of early and/or resistant varieties;
- Adopting good postharvest practices such as rapid drying of products to a safe moisture level;
- Developing infrastructures such as sanitation, and improved storage structures;

The **Regional Workshop of PACA** (Senegal, September 2015) identified the priority actions for technology as:

- Testing: provide affordable and accessible rapid test kits in each AEZ in countries for tests at all critical points of the VC; build capacity in testing laboratories; establish national and regional testing/reference labs; raise awareness; establish M & E at country and regional levels;
- Good Agricultural Practices: create a holistic, integrated approach; create a private sector-led value chain centric aflatoxin management program; consider aerial, area-wide application of aflasafe™ (The Gambia and Senegal) [*Scaling –up is premature. This technology could work better if integrated in a good agricultural practices package. See 2.3: Good pre-harvest agricultural practices*]; develop and deploy low susceptibility varieties;
- Good Production Practices (GPP) and Good Manufacturing Practices (GMP): define recommended technologies (basic - advanced) for every process step (drying, sorting, grading, product segregation, storage and transport); implement the recommended techn vbcologies in the value chain at country level;
- Decontamination: evaluate efficacy of local clay in decontaminating groundnut cake and oil; adopt ammoniation technology for decontaminating groundnut cake; research small capacity filtration and refinement process for groundnut oil.

It is clear from both lists that not all actions involve an innovative technological research agenda; but where research is necessary, the strong involvement of the farmers' organizations, of the public authorities and the civil society is necessary for an impact on public health. The table below largely repeats the text in the bullet points above.

Priority Actions for technology (Regional Workshop of PACA)
1. Testing
Provide affordable and accessible rapid test kits for tests at all critical points of the value chain (VC)
Build capacity in testing laboratories
Establish national and regional testing/reference labs

Raise awareness & strategic communication	
Establish and ensure functioning of M & E at country and regional levels	
2. Good Agricultural Practices	
Create a holistic, integrated approach: Private sector-led Value chain centric aflatoxin management program	
Consider aerial, area-wide application of aflasafe (The Gambia and Senegal). [*Taking into account the limitations as outlined below. See 2.3: Good pre-harvest agricultural practices*], there is need for other option or more research work before scaling-up	
Developing and deploying low susceptibility varieties. *There is need to integrate this with good agricultural practices and handling and packaging. Also attention should be given to the Agro ecological zones factors.*	
3. Good Production Practices (GPP) and Good Manufacturing Practices (GMP)	
Define recommended technologies (basic - advanced) for every process step (drying, sorting, grading, product segregation, storage and transport)	
Implement at country level the recommended technologies in the VC	
4. Decontamination	
Evaluate efficacy of local clay in decontaminating groundnut cake and oil	
Adopt ammonisation technology for decontaminating groundnut cake	
Research small capacity filtration and refinement process for groundnut oil	

2.1. Testing for mycotoxins

The poor infrastructure for testing for mycotoxins is a major bottle neck. Laboratories are under-resourced (equipment), there is often inappropriate equipment (technically); a lack of knowledge of available infrastructure; poor maintenance (in lab and supplier) and the testing facilities are based in inappropriate locations. This can be remediated through the acquisition of appropriate equipment; the assistance to acquire appropriate equipment; the establishment of regional or reference labs. A survey of available infrastructure on the African continent would be most welcome to improve the access of researchers to test facilities in neighbouring countries.

Besides the provision of affordable and accessible rapid test kits for tests at all critical points of the value chain (VC) there is a need to develop novel ways to reduce solvent consumption in residue testing. Food samples can routinely be screened for mycotoxins by liquid chromatography tandem mass spectrometry (LC-MS/MS) at chromatography flow rates that are in excess of 500 microliters per minute in combination with high pressures and smaller particle size HPLC columns to maintain sharp peaks and fast chromatography. These flow rates produce fast speeds and excellent peak shapes and results, but have a draw back in that they require higher volumes of organic solvents - these being acetonitrile and methanol in most methods – which adds to the cost of analysis. Furthermore, they could be an environmental menace if not properly disposed of. Therefore, novel ways to reduce solvent consumption in residue testing would be beneficial to the environment and also reduce the running costs of a testing laboratory.

2.2. Raising awareness of all actors through education, information and knowledge sharing

Awareness on the health and trade impacts of aflatoxin (Regional Workshop of PACA)
Objective
• **Awareness should be evidence based – providing evidence of the impacts (health, ag?, trade), as well as**

actions that work.
- The aflatoxin problem is invisible so greater awareness among the private sector, for example, can enable them to be aware of investment opportunities thus attracting investments.
- Awareness will drive demand for aflatoxin safe food. Once people start demanding, then you have an opportunity for all the other things to kick in. In order to generate demand for aflatoxin safe foods, awareness is needed on the health benefits of aflatoxin safe products.
- It is essential to avoid creating panic.

Activities required

- Training of producers and other value chain actors
- ICT and mobile phone apps to share information and good practices
- Knowledge sharing about good practices

Awareness – three levels:

- Messaging: Impacts of aflatoxin as well as best practices targeted for
- Tools: how to reach intended audiences
- Private sector tools: Supporting the private sector in marketing and communication of aflatoxin free products

Awareness, prevention and management of mycotoxins (1st Symposium on African Mycotoxicology)

Awareness – problems and solutions

- Inadequate focus on target populations
- Target populations: All players along the value chain
- Modes of communication: inter-society networks/fora (e.g. PACA, ASM, ISM, FAO, farmer groups)
- Target communication methods (radio, open days, institutions, opinion leaders cell phone technologies)
- Develop communication methods (so as not to scare farmers)
- Media involvement in scientific meetings (e.g. presence of policy makers to draw media attention)

Prevention- Problems

- Knowledge and access to application of technologies (know how lacking)
- Availability of information to be used in predictive methods e.g weather info
- Lack of incentive/ motivation to apply preventive measures
- Food insecurity
  - Monotonous diets
  - Social dogma regarding food superiority
- Climate change
- Political will to ameliorate farmers losses

Prevention – solutions

- Training and capacity building
- Provide info to value chain players
- Creation and implementation of right/adequate policies and regulations
- Change in cultural practices, mindset, govt intervention, creation of alternative uses
- Involving extension workers

Management – Problems

- High cost of testing (limited resources) for farmers
- Oversight of managers on location
- Poor value chain arrangement (Maize consumed before the regulated markets)
- High surveillance and cost for monitoring agencies
- Lack of political will to sponsor management
- Limited infrastructure to reduce contamination

Management – solutions

- **Formation of partnerships**
- **Cheaper Kits**
- **Regional extension laboratories**
- **Alternative use of contaminated grains**

Effective communication tools for farmers and others involved in the value chain require quality training videos to be developed with farmers who are trained in aflatoxin prevention and management. An inventory will need to be developed of which organisations have conducted farmer training in which countries and on which value chains and aspects of aflatoxin prevention and management. Agro-Insight has started to interact with ICRISAT on identifying possible video modules on groundnut aflatoxin managament in Mali, but experiences from other organisations would be needed to enrich the portfolio of learning tools. The audio-visual materials could be developed in such a way that they will serve as source for future radio programmes and awareness raising.

2.3. Good pre-harvest agricultural practices

Large-scale deployment of aflatoxin biocontrol can immensely benefit African farmers.

A manufacturing plant (capacity 5 tons/hour) has begun to produce Aflasafe™ in Nigeria. Plans are underway to construct small-scale manufacturing plants in Kenya and Senegal. A model for creating sustainable market demand for Aflasafe™ in the maize value chain is being piloted under the AgResults Initiative in Nigeria. Some African governments are providing biocontrol products to smallholder farmers in public health interest and to improve marketability of maize grains.

Scaling –up of aflasafe is premature. This technology could work better if integrated in a good agricultural practices package. The following needs more attention[1].

- *LONG time and HIGH funding level prior to available product – usually it takes 3-5 years to have a testable product for a given country that can be tested in farmers' fields. There is need for specialized people and facilities – so that each strain development would cost between 1-5 mill. of $. Products need to be developed for each country due to ecological situation but also due to regulatory aspects (Convention of Biosecurity – only indigenous strains can be used for biocontrol in a given country; except if prior agreements)*
- *Need for specialized facility for production of aflasafe product – there is need for a highly specialized facility to produce aflasafe which should be available on a regional or country level (this would cost at least 2 mill $ in production and 2-300 000$ annually for running cost*
- *High distribution cost (not affordable by small scale farmers) -since these are bulky inputs with a need of 10kg-ha which need to be distributed to far away locations – who bears this cost, would this be through input distribution scheme or on credit*
- *Use of sorghum as the carrier for fungal spores – this effectively takes out high level of grains in already food insecure areas eg. 10kg per ha; usually farmers have*
- *No visible difference between treated and untreated grains the treatment with aflasafe does not improve the visual quality of the treated commodities, which is one of the ways of achieving higher prices in undeveloped food systems. Only in combination with GOOD Agricultural Practices is there an improvement of the visible quality of the crops.*

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[1] Contribution made by Benoit Gnonlonfin, Food safety specialist INRAB and one of the experts at the Round table

- *Year on Year only about 30 to maximal 50% of the crops have a toxin level beyond the WHO or the EU level respectively so that large amount of fields are treated unnecessarily there is need for a better targeting mechanism to find out years and regions of high risk which could reduce the effort needed for combatting aflatoxin.*
- *Good Agricultural practices have been shown to have a 60% reduction of aflatoxin one of the key steps for any system is sorting which can be mechanized via colour sorters, but there is need to have parallel markets (e.g. feed, oil industries) for bag quality products which need to be absorbed into other product streams.*
- *System of aflasafe is only viable if a quality conscience market is identified – presently most markets in Africa do not have this consciousness and only export market pay higher prices for better quality, but the volumes of export markets are still small.*
- *Need for qualified and decentralized testing capacity for aflatoxin that certifies crops at different levels in the chain so that aflasafe becomes a standard – which adds cost to the final product.*
- *Risk of aspergillus as an allergen and potential risk for aspergillus infecting the lungs is increased with aflasafe since more fungi are available for a short while in the environment; also no protective equipment is worn during distribution of aflasafe product effectively increasing the risk of exposure especially in immunocompromised individuals*
- *No effect on other mycotoxins – aflasafe does not impact levels of other mycotoxins such as fumonisin and ochratoxin A which have similar health impacts since it is a specific biocontrol agent, which are very well controlled by Good Management Practices*
- *Lastly the risk of recombination of Aspergillus atoxigenic strains (aflasafe) with toxigenic strains needs to be evaluated – this is a possibility potentially resulting in a super-strain.*

In-situ detoxification of mycotoxins in genetically engineered crop plants has been demonstrated but such varieties are not available commercially.

Biological control using microbial antagonist strategy has emerged as a promising approach for control of pre-harvest contamination of aflatoxins. The antagonist microorganisms include competitive atoxigenic strains of yeasts or bacteria, and symbiotic fungi (*Trichoderma* spp., *Beauveria* spp., mycorrhiza). In Africa, some microorganisms almost exclusively atoxigenic strains of Aspergillus spp. are already available as branded products. However, several challenges ranging from economic to environmental sustainability have not yet been addressed[2].

A less known yet effective measure to reduce mycotoxin contamination of plant products is their protection against insect pests. Genetically modified crops expressing *Bacillus thuringiensis* proteins active against pests and thus reducing mechanical damage proved efficient in reducing the content of certain mycotoxins, such as fumonisins in maize.

There is a potential of plant extracts to be used as possible flour fortifiers with the ability to reduce toxin production by *Aspergillus* species. Plant extracts have been utilised widely as antimicrobials due to a wide range of secondary metabolites that they possess. Additional research is needed to investigate the ability of some plants extracts in Africa which inhibit the production of aflatoxin.

[2] Ehrlich, K. C., Moore, G. G., Mellon, J. E., & Bhatnagar, D. (2014). Challenges facing the biological control strategy for eliminating aflatoxin contamination. World Mycotoxin Journal, 8(2), 225-233.

2.4. Good postharvest practices

Postharvest management of mycotoxins begins with the separation of infected material from harvested commodities. Manual sorting is an efficient means of reducing mycotoxin exposure suitable for smallholder farmers. Industrial systems remove infected grains one-by-one from grain streams passing optical sensors with a throughput of dozens of tons per hour. There is however a need to develop simpler, more cost-effective driers that may be used at subsistence level.

Storage conditions preventing mycotoxin accumulation include low humidity and low temperature. Stored commodities can also be protected by the exclusion of oxygen, by fumigation or by treatment with preservatives such as propionic acid. Mycotoxins that are already present in the commodity can be destroyed by physical and chemical treatments.

In Africa plastic and other polyethylene packaging materials are widely used for grains and other commodities. This practice also could significantly contribute to worsen the situation.

Contaminated food or feed can be treated postharvest in order to detoxify aflatoxin in the body so that it would present no more risk for human or animal health.

- *Detoxification* can be applied anywhere in the food and feed chains, from the harvest to the distribution of final products. Enzymatic detoxification is the most promising decontamination method because it relies on highly specific catalytic processes and the active agents are proteins, which can be produced by plants and microorganisms. Feed additives binding mycotoxins by physical adsorption and destroying mycotoxins enzymatically are available. Integration of chemical and particularly enzymatic detoxification of mycotoxins into food processing pipelines is currently being evaluated by food companies.
- *Ammonisation* is a costly technology and the final product may be more toxic. There is need to leverage the decontamination by other means.
- *Nixtamilisation* is another option, but applying this approach at a large scale in Africa has not been researched yet. Nixtamalization refers to a process for the preparation of maize (corn), or other grain, in which the grain is soaked and cooked in an alkaline solution, usually limewater, and hulled. However, the detoxified products from nixtamalization can actually be reversed in the digestive system, thus reactivating the aflatoxin1. This may be the case with some of the biological binders as well, such as lactic acid bacteria. Other research questions regarding the binders, are: How do they bind mycotoxins under in vivo conditions? Are there local foods/binders that give protection? Have these been researched?

Recently developed postharvest approaches include the removal of fumonisins from food by natural clay adsorbents, while there is an increased interest in enzymatic degradation of fumonisins in food through decarboxylation and deamination by recombinant carboxylesterase and aminotransferase enzymes.

Cultural specific biologically based intervention strategies could impact positively on food security and the health of rural subsistence maize farming communities that are exposed to high levels of mycotoxins.

Strategic interventions to manage the two *Aspergillus* spp. can greatly contribute to management of the aflatoxin problem in groundnut value chains. Plant health clinics in Sub-Saharan African countries such as Malawi offer opportunities for disseminating extension advisory services on *Aspergillus* spp. and aflatoxin management technologies. In Malawi a total of 42 plant clinics are operating in six districts of Malawi. These have so far diagnosed plant health problems on 56 different crops, including ground nuts where the visible mouldy growth is the obvious evidence of *Aspergillus* infection. Diagnosis and consequent advice to farmers by agricultural extensionists, who are trained as plant doctors under the CABI led Plantwise programme (http://www.plantwise.org), was backed by the use of reference materials in the form of aflatoxin management fact sheets written in a layman's terms and deposited on the Plantwise Knowledge Bank (http://www.plantwise.org/KnowledgeBank/home.aspx), an open access technical resource for plant health.

2.5. Good Manufacturing Practices

Sanitation and improved storage structures
Airtight storage of moist-harvested maize (approx. 34–30% moisture content) combined with biocontrol is a promising, cheap and energy-efficient technique for minimizing mould growth and the risks for mycotoxin production during storage.

There is a need for further evaluation of storage technologies for climatic variables that favor mycotoxin producing fungi to design appropriate storage structure. As other fungal pathogens are also able to produce secondary metabolites, further investigation is required to understand the multiple mycotoxins profile along the maize value chain according to the type of storage structure.

Air-drying cobs reduces the risk for mould growth during storage, but is sensitive to weather fluctuations. Smoke-drying enables greater control of drying, but is costly and detrimental to the environment and health. When grain is harvested and stored moist in airtight conditions, lactic acid bacteria (LAB) naturally initiate fermentation – the decreased pH due to lactic acid production, together with the anaerobic environment, generates a stable storage system in which moulds and other microbes are inhibited. Inoculating grain with the biocontrol yeast *Wickerhamomyces anomalus* (syn. *Hansenula anomala*, formerly *Pichia anomala*) confers additional storage stability. This yeast inhibits moulds and minimizes the risk for mycotoxins via products of glucose metabolism, mainly the volatile, ethyl acetate.

Moisture control is crucial during the storage of raw, intermediate and processed food and feed. Drying is an age-long food preservation technique, with sun- solar-, artificial-, and hybrid-drying, widely practised in Africa to varying levels of sophistication. The relevance of these drying techniques in mycotoxin research is highlighted, with their advantages and limitations. With special reference to solar-drying, different types are presented to guide the choice for drying in Africa. Controlling and managing mycotoxins in Africa will benefit from designing and government- or donor-assisted distributions of appropriate dryers to farmers, (like) as with? improved seeds and farm inputs. This should be supplemented with simplified extension on moisture control, and possibly assisted with smartphone alerts on meteorological changes, akin to storm warnings in developed countries. Storage stability can also be controlled by using natural preservatives from African plants or spices as a green technology. Some African plants with antimicrobial properties are mentioned, with possible ways of harnessing their active components to prevent mycotoxins in materials.

There is a need for research into how traditional food processing in Africa affects mycotoxin levels in various products. The steps in African traditional food processing can involve sorting, grading, salting, drying, pH or acidity changes, fermentation, cooking, steaming, and grilling to different extents. Advanced food processing technologies have been used to decontaminate mycotoxin-contaminated grains. Africa probably needs a dedicated post-harvest and processing centre to research, study and specifically explore how food and nutrition security in the continent can be assisted by effective control and management of mycotoxins in food and feed.

2.6. Decontamination

Waste and livestock feed

When animals are given mouldy grains rejected for human food, the toxins from contaminated feed will move to milk and end up in humans after all.

When cows ingest aflatoxin-contaminated feed, they secrete aflatoxin M1 (AFM1) in their milk. Aflatoxin M1 has been detected in high concentrations throughout sub-Saharan Africa in cow's milk and in human breast milk, putting infants at high risk. The strategy of using food additives, such as antioxidants, to protect livestock may also provide effective and economical new approaches to protecting human populations from the mycotoxin.

Contaminated food or feed can be treated postharvest in order to detoxify aflatoxin in the body so that it would present no more risk for human or animal health. Nixtamilisation is one option, but applying this approach at a large scale in Africa has not been researched yet. Nixtamalization refers to a process for the preparation of maize (corn), or other grain, in which the grain is soaked and cooked in an alkaline solution, usually limewater, and hulled. However, the detoxified products from nixtamalization can actually be reversed in the digestive system, thus reactivating the aflatoxin[3]. This may be the case with some of the biological binders as well, such as lactic acid bacteria. Other research questions regarding the binders, are: How do they bind mycotoxins under *in vivo* conditions? Are there local foods/binders that give protection? Have these been researched?

Converting waste to energy

When contaminated raw or processed products are segregated it can be a source of energy. Contaminated meal or shells offer energy options in rural communities that need off-grid energy. Contaminated grain can be used as a source of bio-energy. By adding value to products that should otherwise have no value there are opportunities to build confidence in chains that handle responsibly contaminated / waste material and should provide some scope to offset some of the costs of other interventions. By converting this material from waste to energy there is also an offset against the cost and energy related to production of this material.

2.7. Integrative PPPP (Public Private Producer Partnership)

Technology interventions should be complemented by good agronomic practices and better pre- and post-harvest management because these are also critical to address the aflatoxin challenge, especially among smallholder producers.

A priority is developing market pull. All of the technologies, controls etc will not make the difference we want unless there is market pull for food with low levels of aflatoxin. This may be driven by regulation or by business that is concerned about reputation or by individuals concern about the health of their family members. Looking at the issues and technologies through the lens of how the market will pull

[3] Méndez Albores, J. A., Villa, G. A., Rio García, D., & Martinez, E. M. (2004). Aflatoxin detoxification achieved with Mexican traditional nixtamalization process (MTNP) is reversible. Journal of the Science of Food and Agriculture, 84(12), 1611-1614.

product through a value chain that has a particular or set of GAP, GPH or regulation or advocacy interventions might be worth considering. There is a need to establish value chains that deliberately remove food or by-products that are contaminated by mycotoxins.

Improved technology to enhance the value chain competitiveness (Regional Workshop of PACA)
Objective
a. Improvement of quality b. reduced levels of aflatoxin
Challenges
a. Establishing a sustainable incentive/motivation to small scale farmers b. Capacity building c. Application of appropriate technology d. Accessibility to market e. Awareness f. Health of the consumers
Activities required
a. Training b. Leverage and scaling-up available technology c. Evaluation of available technology d. Cost benefit analysis of technology e. Production and distribution of aflasafe. *With reference to the limitations, challenges and gaps as outlined above (see: 2.3.), more research work is needed before next steps to better understanding and clarification (e.g. adaptation, environmental studies, etc.). Targeting ecological areas for application of technology* f. Code of practice of aflatoxin along value chain. g. Engagement of media for communication
Expected outcomes and impacts
a. Knowledge and skill development along the value-chain b. Awareness creation c. Adoption of appropriate technology d. Dissemination of available appropriate technology e. Improved health and income.

In the supply chain, processing technology drives everything and is crucial. Processing must be driven by the private sector to ensure sustainability and avoid collapse, which is common in most government driven initiatives. We should also work on seeds, where there are new technologies developed but there is no uptake.

Activities in the whole supply chain
Challenges
• **Value chain analysis (reality is that there are hardly any processors)** • **Link with research (national and regional)** • **Seed – aspergillus resistant, multiple disease resistant and drought resistant, purity of seeds according to maturity duration**   o **develop commercial seed business; Private sector to multiply the seeds;** • **Agriculture: Good agriculture practices, prevention of losses** • **Aggregator collects from xx smallholder/ out grower farmers** • **Postharvest issues: dry to right moisture, select appropriate technology… (NOT at farmers**

level)

- Appropriate storage (with air movement) (NOT at farmers level)
- Pilot traceability system
- Segregation/ testing – (what you do with bad stuff?)
- Incentivize investors in larger scale groundnut processing,
- Support to small and medium scale processors and traders to upgrade capacities; including informal market outlets/ vendors and traders
- Food safety certification of processors/ testing and in handling and storage, based on risk assessment
- Pre-shipment inspections
- Grading (by processors)
- Facilitate business linkages (buyers, processors, traders, farmers) for effective value chains
- Extension/ technical assistance to processors
- Policy / advocacy issues
- Private sector associations – form follows function
- Assess appropriate mechanization (equipment and system) in production
- Assess appropriate mechanization in processing (including electronic sorter, and blanching)
- Communication/ ICT/ awareness creation

Expected outcomes and impacts

- Increase of income for farmers
- Improved health
  - Improved quality of locally consumed groundnut and groundnut products
- Increased productivity
  - Quantity and quality of nut produced
  - Better seeds
- Viable shelling and processing
  - Improved quality
  - Improved capacities
- Increased volumes of export of groundnut
  - Reduced rejection of product

Partners needed to implement the project

- Private sector seed companies
- Buying companies (international, national)
- Service providers
- Aggregator (can also be a sheller or buyer)
- Processing companies and investors willing to go into groundnut processing
- Farmers and Farmers organisations
- Policy makers
- Input suppliers (Aflasafe, equipment suppliers, seed supplier,
- Research
- Machinery (processing, production)

There is need for ranking and prioritization.

This will contribute to the efficiency of actions and ultimately achieving goals and impacts.