Sustainable Cashew & Peanut Small Business Project (AMCANE) Aflatoxin Prevalence Study

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1. Introduction

1.1 Background

The Sustainable Cashew & Peanut Small Business project (hereafter “AMCANE”) is implemented through a public-private partnership between HELVETAS Swiss Intercooperation, the Aga Khan Foundation and PAKKA AG. The overall goal of the project is to increase the sustainability of production systems, foster livelihoods of smallholder farmers and small entrepreneurs, and to enhance the availability of nutritious food of good quality in Northern Mozambique (Cabo Delgado and Nampula province).

A priority focus of the project is the improved management and control of aflatoxin in the peanut value chain. The project aims to identify the prevalence of aflatoxin in peanuts produced in project intervention zones and to analyze the main causes of aflatoxin contamination at crucial stages of the peanut production and post-harvest cycle. The results of this research will help to then identify locally adapted solutions to minimize mycotoxin contents in the peanut value chain. Furthermore, the evidence created by the project shall be used to inform decision makers in Mozambique on how to address this urgent health issue at the policy level, and will propose solutions to peanut market actors on how to manage aflatoxin in their products.

1.1.1 Aflatoxin Management

Prevention or management of aflatoxin contamination may be directed at both the process of contamination and the fungi causing the contamination. The contamination process can be divided into two phases based on crop maturity. The first phase occurs during crop development and is generally associated with physical damage to the crop, typically by either physiologic stress or insect activity. Crop components contaminated during the first phase often fluoresce a bright green-yellow as a result of kojic acid production in crop tissue by the aflatoxin-producing fungi.

After maturation, crops remain vulnerable to contamination, providing a window during which a second phase of contamination may occur. Exposure of the mature crop to both high humidity and temperatures conducive to aflatoxin producing fungi can result in both new crop infections and increases in the aflatoxin content of crop components already infected. The second phase may occur prior to harvest in the field or after harvest during transportation, storage, or at any point until the crop is consumed.

Hot dry conditions during crop development favor the first phase of contamination, whereas rain and high humidity with warm temperatures after crop maturation favor the second phase. Reliable management practices must address both phases. Improving the resistance of cultivars to contamination is one method of simultaneously addressing both phases of contamination. Although proper cultivar selection and crop management can limit vulnerability to both phases, environmental changes can frustrate even the best management practices and result in a highly contaminated crop.

1.1.2 Important Pre-Harvest Factors that Lead to Aflatoxin Contamination in Peanuts

1. **Drought stress (in particular, 4 - 6 weeks before harvest)**

    a. High temperatures and low atmospheric humidity associated with drought stress favor the growth of aflatoxin producing fungi (e.g. through increased soil temperature) while suppressing the growth of other microbes and giving a competitive advantage to the aflatoxin-producing fungi.

    If kernel moisture (kernel water activity) is maintained until harvest, the plant can fight off fungal colonization and subsequent aflatoxin production through its own with natural defense mechanisms.

    - <u>Exception:</u> High insect pressure and extensive pod damage give an advantage to the fungus due to plant stress accompanied by a decrease in plant immunity.

2. **Peanut carbohydrate levels**
    a. Immature and drought-stressed peanuts are reported to have greater carbohydrate (sugar) levels than mature, non-stressed seed. Aflatoxin-producing fungi grow faster on high sugar substrates. Thus, greater carbohydrate levels are linked to increased aflatoxin development in peanuts.
3. **Soil calcium content**
    b. Calcium deficiency leads to increased aflatoxin accumulation. Peanut yield has long been known to be substantially affected by calcium soil levels. While calcium requirements vary with pod development, calcium plays an important role in cellular structural functions, regulating membrane permeability and strengthening cell walls. In peanuts, calcium is absorbed directly by the developing pod from the soil. Drought limits calcium uptake.
4. **Soil arthropods**
    a. Insects may damage pods, destroy roots, or cause pod scarification. Examples of such soil arthropods include: White grubs (Coleoptera: Scarabeidae), millipedes (Myriapoda: Diplopoda), symphilids (Myriapoda: Symphyla), termites (Isoptera: Termitidae), earwigs (Dermaptera: Forficulidae), wireworms (Coleoptera: Elateridae), red ants (Hymenoptera: Formicidae), mealybugs (Homoptera: Pseudoccoccidae), black ants (Hymenoptera: Formicidae), centipedes (Myriapoda: Chilopoda).

1.1.3 Important Post-Harvest Factors that Lead to Aflatoxin Contamination

Aflatoxin can develop at any point in the handling chain.

1. **Pod damage**
    a. The greatest protection of peanuts against fungal contamination is a healthy, undamaged pod. Any kind of damage to the pod will significantly increase the chance of aflatoxin contaminated peanuts within the pod. This is due to the fact that fungal spores can gain entrance through (micro and macro) cracks and holes, propagate on the inside of the pod, and result in spoiled nuts (discoloured, shriveled, mouldy).
2. **Pod moisture content**
    a. It is essential that pods and nuts are dried properly. High moisture content, especially during storage, promotes fungal and subsequently aflatoxin development.
3. **Post-harvest insects**
    a. Chewing insects will cause damage to the pod and provide entry for fungal spores.

1.2 Study Objectives

2020's research objectives were originally:

I. Prevalence and Aflatoxin Development on farm
II. Aflatoxin Prevalence in peanut-producing areas in Mozambique
III. Comparison of different drying methods
IV. Improved quality through hermetic storage

Due to the Covid-19 pandemic, the investigations planned were reduced and our methodology consultant and field advisor, Dr. Victor Kagot, was unable to travel to Mozambique. He continued consulting with the team via phone and e-mail.

The objectives of the revised 2020 research are:

I. Measure, analyze, and compare the **prevalence of aflatoxin in peanuts** in **five districts** of Cabo Delgado and Nampula provinces, based on samples from representative smallholder farmers.
II. Assess the willingness of traders to offer a higher premium for shelled peanuts stored in hermetic bags.

The goal of 2020's investigations are:

I. To determine the magnitude of aflatoxin contamination of peanuts in Mozambique.
II. To establish whether traders would pay a premium for high quality nuts and whether improved quality through storage in hermetic bags was visible to traders.

2. Key Results

Five districts located in two provinces in the northern part of the country took part in the survey. Districts were chosen based on their significance in terms of peanut production. Participating villages (5 per district) and farmers (3 per village) were selected by the in-country field team in each district. In total 75 samples were collected, graded and analyzed for aflatoxins (total amount in ppb).

Investigated Provinces: Cabo Delgado and Nampula
Investigated Districts: n = 5 Erati (Nampula), Meconta (Nampula), Mogovolas (Nampula), Chiuri (Cabo Delgado), Namuno (Cabo Delgado)
Number of villages per district: n = 5
Number of farmers per village: n = 3
Number of farmers per district: n = 15
Total number of samples: n = 75

2.1 Prevalence Study

- Aflatoxin contamination is a widespread problem in peanut growing regions in Mozambique, and
- the occurrence of aflatoxin is not clustered in provinces or districts, which confirms the findings from 2019.
- Aflatoxin contamination levels were slightly higher in 2020 than in 2019.
- 65% of samples collected were below 10ppb (compared to 61% in 2019).
- The incidence of damaged pods four weeks after harvest was 50% higher in 2020 than in 2019.
- Occurrence of moldy pods was the biggest problem for farmers in 2020, and the number of moldy pods was also correlated with aflatoxin contamination.
- Damaged pods were correlated with aflatoxin contamination, which confirms the trend in 2019 where a weak correlation was found between aflatoxin and pod damage.
- On average, nut moisture content 2 to 3 weeks after harvest in 2020 was below 6% in Chiure, Erati, and Namuno, while it was significantly higher in Mogovolas and Meconta, which on average were on average above 6.6%. In 2019, the inadequate drying was attributed to Cyclone Kenneth (80% of farmers reported the cyclone had resulted in higher moisture levels and germination of seeds) but in 2020 the same drying results were seen suggesting an evaluation of drying methods.

2.2 Trader and Hermetic Storage Study

- All traders agree on three main quality parameters:
    - Grain size;
    - Low moisture level;
    - Peanuts need to be free from dust and other foreign material.
- Onward buyers of nuts are interested in the following quality parameters:
    - Moisture (83%)
    - Dust (33%)
    - Damage (33%)
- Small traders have small networks of preferred farmers to source from because those farmers produce the quality they want to buy, an estimated 10% of their supply.
- 66% of large traders had heard of aflatoxin, however, no small trader had heard about it.
- None of the traders surveyed tests for aflatoxin, and no buyer they deal with has told them they need to test for aflatoxin.
- 50% of the large traders who know about aflatoxin worried about it.
- No trader would offer a premium for peanuts with lower levels of aflatoxin.
- Moisture levels has the largest impact on the price received by the farmer.
- 100% of farmers were interested in storing product in hermetic bags if the price is around $0.34 per bag.

2.3 Farmer Practices Survey

- 81% of farmers leave harvested plants in fields to dry: 47% in one heap per **row**, 48% in piles in one heap per **field.**
    - 19% remove the plants to a secure location.
    - 19% farmers have adopted A frame drying after the pods and plants have been in the field for a number of days.
- 41% sort the pods after threshing, removing pods damaged by “insects,” “fungus,” and/or “disease.”
- After shelling, 82% of surveyed farmers then separate good from bad nuts due to nuts being rotten, germinated, small, insect infested, broken.

2.3.1 Trader Insights from the Perspective of Surveyed Farmers

- 82% of farmers deliver one quality of peanuts, i.e. they do NOT deliver varying qualities of peanuts.
- 10% report improving the quality to sell to traders, this reflects the trader survey where traders appear to have special relationships with small numbers of farmers.
- 69% of farmers state that the price does NOT change even if the **moisture level** is higher than normal. The balance of farmers (30%) report that traders deducted an average of 2.8 MZN/KG for higher than normal moisture levels.
- In comparison, 82% of farmers state that the price does change if **insect damage** is higher than normal. 58 farmers (79%) indicate that traders deducted an average of 6.2 MZN/KG for higher than normal insect damage.

- 84% of farmers also report that the price does change if the trader finds a higher amount of damaged and/or diseased nuts than normal. 61 farmers (84%) report that traders deducted an average of 5.5 MZN/KG for higher than normal levels of damaged and/or diseased nuts.

2.3.2 Other Key Findings

- Farmers eat about half of their production, selling or keeping the rest of their pods for the next season's planting.
- 37% were experiencing insect problems with their pods in storage.
- 66% of farmers had noticed a change in quality in their nuts from the first month of storage to the last time they ate from their stored peanuts, citing color and smell changes that affected the flavor of the nut, which was mainly attributed to insect infestation.
- 63% buy peanuts from the market to keep feeding their family once they have exhausted their own stocks.

3. Recommendations for 2021

Based on the 2020 and 2019 findings, we recommend the following investigations in 2021:

I. Comparison of different drying methods (particular attention on mould and insect damage to pods and nuts).
II. Improving quality through hermetic storage.

We would also suggest finding out the willingness of hermetic storage bag providers (such as A to Z) to create distribution links to farmer accessible stores using the evidence of work in Kenya to show there is the potential to create market demand. At the same time, the project could support the private sector to provide a number of demonstrations in villages and investigate the willingness of farmers to pay to improve the quality of their home stored food. The project should then focus on the first adopters who are willing to pay the actual cost of the bag as the entry point and allow time to introduce the technology to other farmers. The main reasons for adopting the bags will be improved visual quality of the grain, and reduce insect problems. The unseen benefit will be the reduced consumption of increasing aflatoxin levels in family meals.

4. Detailed Findings: Prevalence Study

4.1 Aflatoxin Prevalence in the Studied Locations

To assess aflatoxin prevalence, a 2.5kg sample was obtained from 75 farms located in five districts (Namuno, Chiure, Erati, Meconta, Mogovolas) roughly 4 weeks after harvest.[1] Samples were transported to HELVETAS Headquarter in Nampula, graded for damage (see next section), and analyzed for aflatoxin content using the Neogen Reveal Q+ lateral flow system.

Aflatoxin content was analyzed by district (Namuno, Chiure, Erati, Meconta, Mogovolas) using the **G**eneralized **L**inear **M**odel (GLM) for ANOVA (**An**alysis **o**f **Va**riance) analysis (Table 1). The significance level was set at 0.05 (5% risk of concluding that an effect exists when there is no actual effect).

Aflatoxin contamination is a dominant problem in the studied areas. All samples (n=75) tested positive for aflatoxins. If samples are grouped based on an aflatoxin threshold, the magnitude of contamination becomes apparent (Tables 1 and 2). The percentage of samples contaminated with aflatoxin below 2ppb or 10ppb, or above 10, 50, and 100ppb is very similar in 2019 and 2020. However, in 2019 four samples contained aflatoxin values above 400pp with a maximum of 901ppb. In 2020, the most contaminated sample contained 363ppb. Both highly contaminated samples (in 2019 and 2020) originated in Chiure (Cabo Delgado). 10ppb is the regulatory limit for total aflatoxin content in Mozambique. Samples with aflatoxin values above 10ppb should be considered unfit for human consumption under Mozambican law. (For comparison: Regulatory limit in the EU is 4ppb and in the USA 20ppb). Table 1 shows the total incidence of aflatoxin contaminated samples. Table 2 shows the range of aflatoxin contamination (total aflatoxins) and the percentage of samples above 2ppb and 10ppb by district.

Table 1: Incidence (%) of aflatoxin contaminated samples below or above regulatory limit (levels are accumulative including all samples within the range)

	Aflatoxin Threshold	2019 (%)	2019 (%)
	Below 2 ppb	55 (n*=33)	52 (n**=39)
Below regulatory limit	Below 10 ppb	61 (n=37)	65 (n=49)
Above regulatory limit	Above 10 ppb	38 (n=23)	35 (n=26)
	Above 50 ppb	22 (n=13)	19 (n=14)
	Above 100 ppb	20 (n=12)	15 (n=11)
	Above 300 ppb	10 (n=6)	1 (n=1)
	Above 400 ppb	7 (n=4)	0 (n=0)
	Highest aflatoxin content	901 ppb (Chiure)	363 ppb (Chiure)

*n total = 6 (2019).
**n total = 75 (2020).

[1] Initial samples were collected on the day the experiments were set up, i.e. the 22nd of May but only aflatoxin analysis was completed. Second sample collection was done 41 days later on the 3rd of July and both aflatoxin analysis and grading were completed. The third sample collection was done on the 17th of July and aflatoxin analysis and grading were conducted. 15 days later samples were also shown to the traders. Shaded area indicates all samples contaminated below the regulatory limit of 10ppb total aflatoxins in Mozambique.

Table 2: Range of aflatoxin levels and the percentage of samples above 2ppb or 10ppb by district

	2020			**2019**		
District (Province)	Range of aflatoxin levels ppb	% of samples above 2ppb	% of samples above 10ppb	Range of aflatoxin levels ppb	% of samples above 2ppb	% of samples above 10ppb
Namuno (Cabo Delgado)	0.5 – 90	60.0	40.0			
Chiure (Cabo Delgado)	0.5 – 363	53.3	26.7	0.8 - 901	53.3	46.7
Erati (Nampula)	0.5 – 291	66.7	46.7	0.5 - 370	46.7	40.0
Meconta (Nampula)	0.5 – 234	26.7	26.7	1.2 - 445	53.3	40.0
Mogovolas (Nampula)	0.4 – 249	33.3	33.3	0.6 - 471	33.3	26.7

The results from all farmers can be seen in **Annex A.**

Aflatoxin contamination did not cluster in certain locations or villages and seemed to be a relatively homogeneous problem in the studied areas (Table 2). This is consistent with the 2019 results. For example, the number of samples containing more than 100ppb was as followed: Chiure (n=4), Erati (n = 3), Mogovolas (n=3), and Meconta (n=2).

In two villages, Milipone-Nacahe (Cabo Delgado) and 25 de Setembro-Mucuaia (Nampula), all samples were below 10ppb. In six villages one out of five samples was above the 10ppb threshold. In three villages two out of five samples were above the 10ppb limit. In one village three samples and in two villages, Pambara-Potomola (Cabo Delgado) and Namapa sede-Nacole (Nampula) four samples out of five were unfit for human consumption.

4.2 Pod Damage in the Studied Locations

The 2.5kg sample was graded based on the following pod damage categories: broken pods (mechanical damage); pods with visible insect damage; and pods with visible discolouration and/or mould infestation. The total proportion of damaged pods (Damaged pods = broken pods plus insect damage plus mould/discolouration) was calculated for each sample:

- **Damage incidence in the complete sample (%) = (Number of <u>all damaged</u> pods/Total number of <u>all pods</u>)*100**

Also, to assess if any damage category was more prevalent than another, the incidence of individual damage within the damaged proportion of the sample and the total 2.5kg sample was calculated, e.g.:

- **Insect Damage incidence in the damaged proportion of sample (%) = (Number of insect damaged pods/Total number of <u>damaged pods</u>)*100**
- **Insect Damage incidence in the complete sample (%) = (Number of insect damaged pods/Total number of <u>all pods</u>)*100**

However, sorting and grading has some bias, since mould covered pods may also have insect damage which is not apparent anymore (holes might be overgrown with fungal mycelium). In 2019, the same ranking was seen (incidence of mouldy/discoloured > insect > broken). Incidence of damage was analyzed by district (Namuno, Chiure, Erati, Meconta, Mogovolas) using the **G**eneralized **L**inear **M**odel (GLM) for ANOVA (**An**alysis **o**f **Va**riance) analysis. The significance level was set at 0.05 (5% risk of concluding that an effect exists when there is no actual effect).

4.3 Total Pod Damage

Total damage incidence (based on 2.5kg weight) ranged from 3.5 to 47.6% (average of 20%, in 2019 average was 12%).

In general, the number of damaged pods was statistically similar among districts (Table 4a).

- 16 farmers (21%) had less than 10% of their pods damaged.
- 59 farmers (79%) had more than 20% of their pods damaged.
- However, in 2019, only 13% of farmers had more than 20% of pods damaged. We do not know what caused the increase in damaged pods between in 2020.
- Only 3 farmers (4%) had 40% or more pod damage.

Table 3a: Average Number and Weight of Good Pods in Different Districts

Province	**District**	**Pods**	
		Weight (g)	Number
Cabo Delgado	Chiure	1945	2286 bc
Nampula	Erati	1915	2592 abc
Nampula	Meconta	2112	2988 a
Nampula	Mogovolas	2050	2824 ab
Cabo Delgado	Namuno	1956	1991 c

Mean with the same letter within columns indicate significant differences (a = 0.05) among districts. Means are calculated based on 15 samples per district. Each sample was 2.5kg.

Table 4a: Average Number and Weight of Bad Pods in Different Districts

Province	**District**	**Pods**	
		Weight (g)	number
Cabo Delgado	Chiure	555	717
Nampula	Erati	585	767
Nampula	Meconta	388	811
Nampula	Mogovolas	450	1028
Cabo Delgado	Namuno	544	652

Mean with the same letter within columns indicate significant differences (a = 0.05) among districts. Means are calculated based on 15 samples per district. Each sample was 2.5kg.

If broken down into categories, the following damage to pods was seen:

- 15% moldy pods;
- 4% discolored pods;
- 3% insect damage; and
- 2% broken pods.

4.4 Insect Damaged Pods

The average total incidence of insect damage in a 2.5kg pod sample is 2.62% in 2020 (2019 was 2.9%). If only the damaged proportion of the pods are assessed, 13% of damage originates from insects.

- The number of insect damaged pods was significantly higher in Chiure than in Meconta, Mogovolas and Namuno (Table 5a). This is consistent with results from 2019.

Table 5a: Number and weight of insect damaged pods in different districts

Province	**District**	**Pods**		
		Weight (g)	number	Weight (g) per pod
Cabo Delgado	Chiure	103	161 a	0.64
Nampula	Erati	116	102 ab	1.14
Nampula	Meconta	20.7	60.7 b	0.34
Nampula	Mogovolas	21.3	66.6 b	0.32
Cabo Delgado	Namuno	66.5	85.7 b	0.78

Mean with the same letter within columns indicate significant differences (a = 0.05) among districts. Means are calculated based on 15 samples per district. Each sample was 2.5kg.

4.5 Discolored Pods

The number of discolored pods was statistically similar in all districts (Table 6a). If only the damaged proportion of the pods are assessed, 19.5% of the damage was discoloration.

Table 6a: Number and weight of discolored pods in different districts

Province	**District**	**Pods**	
		Weight (g)	Number
Cabo Delgado	Chiure	89.5	98
Nampula	Erati	117.8	133
Nampula	Meconta	66.9	96.5
Nampula	Mogovolas	64.5	117
Cabo Delgado	Namuno	123.1	126

Mean with the same letter within columns indicate significant differences (a = 0.05) among districts. Means are calculated based on 15 samples per district. Each sample was 2.5kg.

4.6 Moldy Pods

The incidence of mouldy pods was the greatest problem for farmers. On average, 15% of the crop showed this damage (range 0 to 66.6%). If only the damaged proportion of the pods are assessed, 60.2% of damage originates from mould. In contrast, only 7% of pods showed signs of mould/discolouration in 2019. This is interesting since in 2020 we sampled earlier than in 2019 and 2019 was impacted by the cyclone. It implies other factors (possibly related to the growing conditions) are contributing to this problem.

The number of mouldy pods was significantly higher in Mogovolas compared to Namuno and Chiure (Table 7a).

Table 7a: Number and weight of moldy pods in different districts

Province	District	Pods	
		Weight (g)	Number
Cabo Delgado	Chiure	325	363 b
Nampula	Erati	316	471 ab
Nampula	Meconta	274	542 ab
Nampula	Mogovolas	339	729 a
Cabo Delgado	Namuno	328	353 b

Mean with the same letter within columns indicate significant differences (a = 0.05) among districts. Means are calculated based on 15 samples per district. Each sample was 2.5kg.

4.7 Broken and Empty Pods

The number of mechanically broken and empty pods was statistically similar in all districts (Table 8a).

Table 8a: Average Number and weight of broken and empty pods in different districts

Province	District	(Mechanically) Broken pods		Empty pods
		Weight (g)	Number	Number
Cabo Delgado	Chiure	37.9	50.0	43.9
Nampula	Erati	35.0	55.5	26.8
Nampula	Meconta	27.0	55.6	64.3
Nampula	Mogovolas	25.3	59.9	55.7
Cabo Delgado	Namuno	35.1	46.3	41.3

Mean with the same letter within columns indicate significant differences (a = 0.05) among districts. Means are calculated based on 15 samples per district. Each sample was 2.5kg.

4.8 Nut Damage in the Studied Locations

After grading, all pods were shelled and a 2.0kg random subsample of nuts were examined. In general, peanuts were regarded as bad when they showed signs of discolouration, insect damage, mould, shriveling or any other kind of atypical appearance. Peanuts were regarded as good if appearance was typical for the peanut at that specific stage of investigation (after harvest, storage, etc.). The number and weight of bad and good nuts was determined. However, it was not distinguished if a bad nut came from a good pod or a bad pod.

Previous studies have shown that damaged nuts contain most aflatoxin. If damaged pods were removed early in the post-harvest handling to try to remove the potential source of aflatoxin contaminated nuts, farmers would face a 10 to 90% loss of their harvest, depending on the year. For example, in 2020, 79% of farmers would have lost a minimum of 20% and 4% more than 40% of their harvest. Since these nuts are also poisonous to domestic animals (in particular birds), and the toxin is transferred via milk of lactating animals (cows), the damaged peanuts should not be used as animal feed and are therefore considered a total loss since there is no safe use for them.

Currently, traders do not see aflatoxin as an issue (half know nothing about it) and there is no premium at the farm or lower level trading steps for an aflatoxin free product. It is unreasonable to imagine that farmers will carry the cost of mitigating for this without compensation. For a small scale farmer this tradeoff is not feasible, especially since aflatoxin is an invisible danger, and aflatoxin mitigation programs, such as a combination of pest control, sorting, biocontrol, and proper drying and storage options, need to be established sustainably (i.e. the market needs to compensate farmers for the costs of supplying improved quality nuts). No single solution will lead to the needed success when combating aflatoxin's contagion effects – multiple interventions at various stages need to be implemented in order to increase income to the farmer for increased efforts to improve the quality of the nuts delivered to the market.

4.9 Overall Nut Damage

Good nuts are likely contained in good (healthy) peanut pods but also, to a lesser extent, in damaged pods. The data presented below reflects number and weight of a 2.0kg subsample of nuts from the overall 2.5kg sample. As seen in Table 3a, Meconta had significantly more healthy nuts than any other district. Namuno had significantly less healthy nuts than Erati and Meconta, based on weight and number. However, the average weight per nut was higher in Cabo Delgado than Nampula.

Namuno had significantly more damaged nuts than other districts (Table 3b). Furthermore, the weight of the damaged nuts was the same as the weight of good nuts, which implies damage to the nut after maturity rather than something effecting the grain earlier (though this weight data may be inaccurate).

Table 3b: Average Number and weight of good nuts in different districts

Province	District	Nuts		
		Weight (g)	Number	Avg weight per nut (g)
Cabo Delgado	Chiure	1673 bc	3232 bc	0.5
Nampula	Erati	1767 ab	4524 b	0.4
Nampula	Meconta	1828 a	6012 a	0.3
Nampula	Mogovolas	1782 ab	4119 bc	0.4
Cabo Delgado	Namuno	1567 c	3136 c	0.5

Mean with the same letter within columns indicate significant differences (a = 0.05) among districts.
A total of 2kg of peanuts were graded per sample, 15 samples per district. Significance was not evaluated for the average weight per nut.

Based on weight, the volume of bad nuts (all categories) is significantly more in Namuno compared to Erati, Meconta and Mogovolas but not Chiure. Meaning the district Nampula has significantly less bad nuts than the district of Cabo Delgado (based on this prevalence study).

Also, the incidence of bad nuts found in Meconta was significantly lower than in the Province of Cabo Delgado. This confirms the data seen in Table 3b.

The percentage of damaged nuts from the 2kg sample in 2020 was 13.84% (11.89% if Namuno is excluded) compared with 10.25% 2019. This means that at an earlier point in the season there was already more damaged nuts in 2020 than in 2019.

Table 4b: Average Number and weight of bad nuts in different districts

Province	District	Nuts	
		Weight (g)	number
Cabo Delgado	Chiure	327 ab	1291
Nampula	Erati	233 bc	1073
Nampula	Meconta	173 c	963
Nampula	Mogovolas	218 bc	1198
Cabo Delgado	Namuno	433 a	1456

Mean with the same letter within columns indicate significant differences (a = 0.05) among districts. Means are calculated based on 15 samples per district. Each sample was 2.0kg.

4.10 Bad Nuts: Insect Damage

Even though Chiure and Erati had a higher number of insect damage pods, the number of insect damaged nuts is statistically similar among districts. On average, 1% of nuts show signs of insect damage. (Table 5b).

There are several possible explanations to this issue:

- The insect had not had enough time to chew threw pods and seeds in the soil. In this case the damage causing insect would be soil born and not belong to the storage pests.
- The insect had chewed through the pods, but not yet damaged the seeds during the post-harvest period.
- Insect activity was generally slow in 2020.
- The occurrence of mold may have masked the insect hole and nut was classified as mold damage and not insect damage.

However, none of these possibilities can be proven at this point. The average weight of a good nut is 0.43gms whilst the average weight of an insect damaged nut is 0.26gms (after removing the data from Namuno which appears to be wrong). This means that an insect damaged nut has lost 33% of its weight. With the incidence of damaged nuts within the sample at 2 to 3 weeks being only 0.4% (4kgs in 1 MT), this is a small post-harvest loss. It, of course, increases over time.

Table 5b: Average Number and weight of insect damaged nuts in different districts

Province	**District**	**Insect damaged Nuts**	
		Weight (g)	Number
Cabo Delgado	Chiure	9.3	30.7
Nampula	Erati	8.5	30.1
Nampula	Meconta	7.1	26.2
Nampula	Mogovolas	6.9	36.0
Cabo Delgado	Namuno	4.3	12.6

Mean with the same letter within columns indicate significant differences (a = 0.05) among districts. Means are calculated based on 15 samples per district. Each sample was 2.0kg.

The volume of discolored nuts was significantly heavier in in Namuno (Cabo Delgado) compared to any other district.

However, the number of discolored nuts was statistically similar in all districts and Provinces (Table 5b). That said proportionally there are more discolored nuts in samples from Namuno, therefore on visual inspection by traders these nuts will be less desirable. Considering that bad nuts (in general) are also significantly heavier than nuts from other regions, variety and/or agricultural practices (fertilizer/more rain?) could play a role.

Table 6b: Average Number and weight of discolored nuts in different districts

Province	**District**	**Discolored Nuts**	
		Weight (g)	Number
Cabo Delgado	Chiure	41 b	116
Nampula	Erati	35.2 b	139
Nampula	Meconta	37 b	188
Nampula	Mogovolas	27.2 b	118
Cabo Delgado	Namuno	100 a	214

Mean with the same letter within columns indicate significant differences (a = 0.05) among districts. Means are calculated based on 15 samples per district. Each sample was 2.0kg.

In Meconta and Mogovolas, mouldy nuts weigh significantly less than in Chiure and Erati (Table 7b).

Table 7b: Average Number and weight of moldy nuts in different districts

Province	District	Moldy Nuts	
		Weight (g)	number
Cabo Delgado	Chiure	43.2 a	154
Nampula	Erati	47.1 a	174
Nampula	Meconta	18.7 b	78.1
Nampula	Mogovolas	19.6 b	93.5
Cabo Delgado	Namuno	38.7 ab	134

Mean with the same letter within columns indicate significant differences (a = 0.05) among districts. Means are calculated based on 15 samples per district. Each sample was 2.0kg.

The average number of shriveled nuts in Cabo Delgado is 1040 compared to 784 in Nampula. This is just a trend and should be overserved over time. Based on weight, shriveled nuts weigh significantly more in Chiure than in Meconta (Table 8b).

Table 8b: Average Number and weight of shriveled nuts in different districts

Province	District	Shriveled nuts	
		Weight (g)	number
Cabo Delgado	Chiure	234 a	990
Nampula	Erati	143 bc	731
Nampula	Meconta	110 c	670
Nampula	Mogovolas	164 abc	950
Cabo Delgado	Namuno	223 ab	1089

Mean with the same letter within columns indicate significant differences (a = 0.05) among districts. Means are calculated based on 15 samples per district. Each sample was 2.0kg.

In 2020, 2 to 3 weeks after harvest, three districts had average moisture levels below 6%, while Meconta and Mogovolas had moisture content levels of 6.71 and 6.62% -- significantly higher than in Chiure, Erati and Namuno (Table 9). Storing in hermetic bags is recommended for peanuts with a moisture level of 8% or less. When the storage experiment started, all farmers were below 8% moisture content, therefore the introduction of hermetic storage will not be constrained by too high of moisture levels in the peanuts.

While there was a significant difference in the higher moisture levels in Meconta and Mogovolas compared to other districts, there was no correlating higher aflatoxin level. However, Mogovolas did have significantly more mouldy pods than any other district but it does not appear to have resulted in a significantly higher number of mouldy nuts. The data suggests that Meconta and Mogovolas were earlier in their post-harvest cycle than the other districts (which only the field crew can confirm).

In 2019, 25% of samples were below 5.5%, whereas in 2020 only 3% of samples were below 5.5%. However, it is important to note that 2020 sampling was done much earlier than 2019 sampling.

Between districts no significant difference in aflatoxin contamination values were found (Table 9) showing that aflatoxin contamination is not clustered in districts but a problem in all peanut growing regions. However, the average aflatoxin contamination is above the regulatory limit of 10ppb in all districts.

Table 9: Moisture, temperature and aflatoxin content of peanuts samples from different districts

Province	District	Moisture	Aflatoxin (ppb)
Cabo Delgado	Chiure	5.80 b	50.5
Nampula	Erati	5.97 b	29.9
Nampula	Meconta	6.71 a	26.0
Nampula	Mogovolas	6.62 a	59.1
Cabo Delgado	Namuno	5.79 b	23.3

Mean with the same letter within columns indicate significant differences (a = 0.05) among districts.

If broken down into categories, the following damage to nuts were seen:

- 14% of the total weight of the samples were damaged;
- 2% mold (12% of damaged nuts were moldy);
- 2% discolored nuts (17% of damaged nuts were discolored);
- 0.4% insect damage (3% if damaged nuts were insect damaged);
- 9% shriveled (63% of damaged nuts were shriveled).

5. Correlation Analysis

Correlation analysis indicates **some** significant correlation between aflatoxin and grading variables. In 2020 there was a significant correlation between damaged pods and aflatoxin content at r = 0.0367 (Table 10). Also, a weak correlation was seen between aflatoxin content and number of moldy pods at r = 0.0239 (Table 10). In 2019 only a very weak correlation was only found between (%) damaged pods in the sample and aflatoxin content (r = 0.34540).

Positive correlations were found between the different grading parameters of pods (Table 10), nuts (Table 11) and between pods and nuts (Table 12). The overall damaged pods are very significantly correlated with the incidence of moldy pods, indicating that, in 2020, mold was the greatest problem for peanut farmers. Also, discoloration and insect damaged correlated with the overall damage, but the correlation was weaker (Table 10).

Table 10: Correlation analysis – aflatoxins, grading parameters of pods

	Aflatoxin (ppb)	Aflatoxin log	Good pods	Damaged pods	Insect damaged pods	Broken Pods	Moldy pods	Discolored pods
Aflatoxin (ppb)	1	0.84179	-0.08827	0.24331	0.12738	0.04121	0.26067	0.03410
Aflatoxin-log	0.84179	1	-0.16472	0.22791	0.10264	0.11908	0.22238	0.05365
Good pods	-0.08827	-0.16472	1	0.07979	0.07982	-0.02626	0.08004	-0.05651
Damaged pods	0.24331	0.22791	0.07979	1	0.23972	0.43070	0.93206	0.23134
Insect damaged pods	0.12738	0.10264	0.07982	0.23972	1	0.23292	0.08625	-0.02796
Broken Pods	0.04121	0.11908	-0.02626	0.43070	0.23292	1	0.27079	0.29681
Moldy pods	0.26067	0.22238	0.08004	0.93206	0.08625	0.27079	1	-0.05274
Discolored pods	0.03410	0.05365	-0.05651	0.23134	-0.02796	0.29681	-0.05274	1

Yellow highlighted are highly significant correlations at P>r <0.0001, Highlighted in grey are weaker significant correlations.

Correlation analyses showed that insect damage is weakly linked to aflatoxin contamination (Table 11). This means that a nut with an insect hole has a greater chance of containing aflatoxins than, e.g. a discolored or shriveled nut. Since insect damage, discoloration, mold and shriveled appearance are grading categories, they all correlate with ‘bad nuts’. However, the feature ‘shriveled’ is linked most strongly to the appearance of a bad nut (Table 11).

Table 11: Correlation analysis – aflatoxins, grading parameters of nuts (seeds)

	Aflatoxin (ppb)	Aflatoxin log	Good nuts	Bad nuts	Insect damaged nuts	Discolored nuts	Moldy nuts	Shriveled nuts
Aflatoxin (ppb)	1	0.84179	-0.02733	-0.00213	0.39372	0.02206	0.14369	-0.06705
Aflatoxin-log	0.84179	1	0.02686	-0.01226	0.23816	-0.01520	0.22784	-0.07148
Good nuts	-0.02733	0.02686	1	0.25364	0.10751	0.04562	0.01332	0.25205
Bad nuts	-0.00213	-0.01226	0.25364	1	0.30425	0.29649	0.28171	0.90275
Insect damaged nuts	0.39372	0.23816	0.10751	0.30425	1	0.07672	0.08217	0.22589
Discolored nuts	0.02206	-0.01520	0.04562	0.29649	0.07672	1	-0.03272	-0.08705
Moldy nuts	0.14369	0.22784	0.01332	0.28171	0.08217	-0.03272	1	0.10046
Shriveled nuts	-0.06705	-0.07148	0.25205	0.90275	0.22589	-0.08705	0.10046	1

Yellow highlighted are highly significant correlations at P>r <0.0001, Highlighted in grey are weaker significant correlations.

As expected, good nuts are mainly found in good pods and damaged pods harbor most bad nuts. Insect damaged pods also harbored most moldy nuts, as the strong correlation in Table 12 indicates.

Insect damaged pods were not correlated with aflatoxin content (Table 10). Only insect damaged nuts are weakly correlated with aflatoxin (Table 11). However, insect damaged pods strongly correlated with moldy nuts (Table 12), which makes sense since the fungus gains entry through insect holes. This might also explain the low amount of insect damaged nuts through intensive occurrence of fungal mycelium, as explained above.

Table 12: Correlation analysis between pods and nuts grading parameters

	Good pods	Damaged pods	Insect damaged pods	Moldy pods	Broken pods	Good nuts	Bad nuts	Insect damaged nuts	Moldy nuts	Shriveled nuts
Good pods	1					0.39694	0.09619	0.15897	0.03519	0.16056
Damaged pods		1				-0.06808	0.29444	0.29444	0.1000	0.28131
Insect damaged pods			1			0.07275	0.20700	0.20841	0.53081	0.11873
Moldy pods				1		-0.15749	0.24062	0.37560	0.03397	0.19666
Broken pods					1	-0.03479	0.19041	0.19647	0.15453	0.08890
Good nuts	0.39694	-0.06808	0.07275	-0.15749	-0.03479	1				
Bad nuts	0.09619	0.29444	0.20700	0.24062	0.19041		1			
Insect damaged nuts	0.15897	0.29444	0.20841	0.37560	0.19647			1		
Moldy nuts	0.03519	0.1000	0.53081	0.03397	0.15453				1	
Shriveled nuts	0.16056	0.28131	0.11873	0.19666	0.08890					1

Yellow highlighted are highly significant correlations at P>r <0.0001, Highlighted in grey are weaker significant correlations. Shaded blue is nut to nut or pod to pod correlations (those can be found in Tables 17 and 18).

5.1 Discussion

- In 2020, the point of collecting the samples was about 2 weeks earlier in the post-harvest period than in 2019. So while the proportion of samples this year above 10ppb was lower than 2019, it may not have been if the sample collection had been at 4 weeks.
- A surprising finding was that although most of the samples were dryer in 2020 than in 2019 (which suffered from the cyclone and was later in the season), more of the pods looked discolored and moldy.
- The most prevalent damage problem in shelled nuts is shriveled nuts which is determined long before harvest and relates to GAP. 9% of shelled nuts were categorized as shriveled and it made up 63% of the damage category. While the farmer may remove the shriveled nut to eat as the family, they represent a loss on return in investment. Improving GAP resulting in a reduction in shriveled nuts should reduce the cost of production and increase profit.
- The occurrence of insect damaged pods weakly correlates with the presence of moldy nuts (more strongly than moldy pods)
- An insect damaged nut also weakly correlates with the presence of aflatoxin. Given that only 0.4% of the shelled nuts had insect damage the loss in revenue if they were removed entirely

equates to MZN 0.23/kg (MZN225 ($3.16) per MT. However, given traders' lack of interest in aflatoxin at the moment it's not a priority in terms of market access. Given farmers are eating 50% of their stocks introducing hermetic storage may mitigate some of these problems. Linking hermetic storage which would arrest further aflatoxin and insect damage development to on farm storage for home consumption may at the very least prevent families eating increasing levels of aflatoxin over the year.

6. Detailed Findings: Storage and Trader Study

Hermetic storage after drying will arrest aflatoxin development and insect activity during storage, and has been extensively reported to maintain quality during storage (S Walker et al., 2018, Comparative effects of hermetic and traditional storage devices on maize grain: Mycotoxin development, insect infestation and grain quality; Journal of Stored Products Research 77, p33-43). In order to function, peanuts need to be dried to a safe moisture level. The appropriate moisture content before storing peanuts hermetically is 7 to 8 percent for both shelled and unshelled peanuts. Moisture content above 8 percent (around 10% or even more) could compromise the quality of peanuts even if you store in hermetic containers.

The team set out to investigate if farmers and traders perceive a difference in peanut quality of hermetically stored peanuts compared to traditionally stored peanuts. The team investigated if traders would pay a premium for better quality and if the premium could cover the costs for hermetic storage bags and whether issues around aflatoxin would affect their decisions.

After farmers had dried their pods, they were asked to shell the nuts, then two bags of nuts were mixed together. Half the nuts were placed in a hermetic bag and the other half was placed in the normal PP bag. While there was concern whether or not the nuts would be at a suitable moisture level for storing in hermetic bags, all farmers had nuts with a moisture level of below 8%. After 56 days the team returned to the farm and collected a sample from each bag. These samples were then shown to the traders.

Unfortunately, there was a misunderstanding in the way the samples were presented to the trader. While the traders could clearly differentiate varying qualities, and would sort what they perceived as normal and above normal qualities into different bags. Given each farmer started with different quality levels, we needed to record whether there was a noticeable difference in quality between the two bags from the one farm as the traders sorted a number of farmer bags into different quality piles. Unfortunately, this was not recorded. We are unable to tell whether for the same source of peanuts, traders could see a difference in storage quality, and whether that difference resulted in an improved quality.

However, the trader survey did reveal the following information:

- The traders interviewed by the project team fell into two categories and for the purpose of this report they will be called small traders and large traders; above this are large export traders.
- Small traders buy between 4 to 10MT per season;
- Large traders buy between 100 to 300MT per season.
- All traders were also working in at least 3 other commodities, mainly cashew and sesame, but also pigeon pea, cowpea, beans, maize, and cassava.
- Peanuts were the most important commodity to 66% of small traders and 33% of large traders.
- Small traders pass the peanuts on to larger traders and the local market, while large traders pass their purchases onto to export traders who are exporting mainly to Kenya and South Africa (smaller amounts to Malawi and Tanzania).
- 33% of large traders sell on immediately after buying, while all other traders store for a period of time.
- **All traders agree on three main quality parameters:**
    - **Grain size**
    - **A low moisture level**
    - **Free from dust and other foreign material**

- 100% of large traders pay no quality premium for good quality peanuts, while 66% of small traders pay a quality premium.
- This implies that market disaggregation happens at the small trader level with poorer peanuts going into the local market, and fair/premium quality peanuts being moved on to the larger traders. Small traders also pay a premium for really good quality peanuts, and given that the larger traders were not paying a premium for these nuts and that the qualities are not large, we speculate that the small traders also have some very specific quality buyers.
- All traders reported a premium for better quality peanuts (even if they did not offer it!), on average of 15MZN/kg. Based on the assumed per kg rate, this means premium quality peanuts are worth about $986/MT and that the premium is between $170 to 211/MT.
- 66% of the small traders state that between 94 to 100% of the peanuts they buy are premium peanuts, the remaining 33% split it half and half.
- Large traders, perhaps because they do not buy poorer quality peanuts, say their premium purchases range from 2% to 48%of their total purchases.
- Small traders have small networks of preferred farmers to source from because those farmers produce the quality they want to buy. Large traders do not.
- Small traders who buy poor and good quality nuts make sure they store the different qualities in identifiable storage areas (i.e. split storage).
- These preferred farmers may supply less than 10% of the total purchases; however, this information was not clear in the survey and needs verifying.
- Market demand varies each year.
- **Onward buyers of nuts are interested in the following quality parameters:**
    - **Moisture (83%)**
    - **Dust (33%)**
    - **Damage (33%)**
- 67% of all traders say that meeting the moisture quality parameter is the hardest to achieve.
- At least 66% of traders store on pallets and 33% of small traders apply chemicals to control pests.
- 66% of small traders sort the nuts before selling on, and 33% of the large traders do the same.
- 66% of large traders had heard of aflatoxin, but no small trader had heard about it.
- No traders test for aflatoxin and no buyer they deal with has told them they test for aflatoxin.
- 50% of the large traders who know about aflatoxin worried about it.
- 83% of traders could see different qualities in the samples presented.
    - 100% of traders were able to separate into different piles, but as mentioned before, without the pairing of the farmer bag data it’s impossible to see whether there was a visible difference between hermetic and non-hermetic storage of the same product.
- No trader would currently offer a premium for peanuts that have a lower level of aflatoxin.

- 66% of small and larger traders claimed they would pay for aflatoxin testing if the test cost $30 or less.
- Moisture levels have the most impact on the price. One small trader reported that he preferred and would pay more for Nametil and Momane peanut varieties,

After the traders survey, the team went back and asked the farmers their opinion about the quality of their stored peanuts. The findings are as follows:

- All farmers (100%) could see a difference between peanuts stored in hermetic bags and polypropylene (PP) bags;
- 30% thought the peanuts stored in hermetic bags were a better colour than the peanuts stored in PP bags;
- 30% thought the peanuts stored in hermetic bags were less discoloured than the peanuts stored in PP bags;
- 80% of farmers thought there was a difference in their mouldy nuts and 87.5% of those farmers thought that the hermetic bags had less mouldy peanuts;
- All farmers (100%) identified hermetically stored peanuts as having less insect damage;
- 50% of farmers found that the hermetic bags had less dust, and 10% found that the peanuts stored in hermetic bags smelled better;
- When prompted, 90% of farmers said the hermetic nuts smelt better;
- All farmers (100%) reported that they would prefer to eat peanuts from hermetic bags given that they judged them to be of better quality;
- The average price they would pay in the market for peanuts stored in PP bags was 81.5MZN/kg whereas the average price they would pay for hermetically stored peanuts was 100MZN/kg, a premium of 18.5MZN per kg);
- On average, a farmer would pay 27MZN per bag ($0.38)
    - Men indicated a slightly higher willingness to pay than women with a range of 15 to 50MZN, a median 34MZN per bag.
- 60% of farmers bought their farm supplies from the main village which ranged from 1.5 to 20km away
    - 40% of farmers purchased their farm supplies from Nampula, 70km away.
- While they were not asked whether they stored peanut seeds (for growing), farmers indicated that they would store more than just peanuts in the bags, i.e. 100% would store peanuts; 80% beans; 30% maize; 30% sesame; 10% sorghum.

Both traders and farmers talk about a premium difference of about 10MZN per kg between normal peanuts and good peanuts. This equates to $140/MT. Hermetic bag costs should be less than $30 per MT, and with care would last two seasons.

Farmers in this year's survey report storing pods for 30 days before selling to the traders, and some even store for longer periods. If storing in hermetic bags resulted in a visible difference in quality after this period that was followed by a price premium, there is an opportunity for the project to introduce hermetic storage as a method to increase the market price. Farmers saw that hermetic storage kept peanuts in better condition, and reported a preference to eat peanuts stored in this way. While at the beginning it will only be the more innovative and well-off farmers who take up this practice, the adoption of such technology slowly through the community will have an impact on the levels of aflatoxin family's are exposed to on a daily basis.

7. Detailed Findings: Farmer Survey

7.1 General Insights

- Of the 73 farmers who participated, 55% were men.
- Farmers were selected from 3 districts of Nampula (Meconta, Mogovolas, Erati) and 2 of Cabo Delgado (Chiure, Namuno).
- The median household contained 2 adults and 3 children, with 84% of surveyed farmers reporting that their children are in school, which is on par with country wide statistics.
- 75% of men and 52% of women report owning a mobile phone.
- The average farmer cultivates peanuts on 1.46ha and produced a harvest of 305kg of peanuts in 2019/20 and 418kg in 2018/19. This is approximately 262kg/ha and 324kg/ha respectively (however there appear to be data collection issues).
- 82% of farmers report eating peanuts during the harvest to marketing phase on a daily basis.
- Farmers eat about half of their production, selling or keeping the rest of their peanut pods for the next season's planting:
  - There are few seed companies in operation and those that are do not sell self-pollinating ones, but hybrid seeds.
  - Continued use of saved seeds reduces future peanut productivity
  - Pest infestation during prolonged storage increases the risk to the farmer of saving seed for the following season instead of selling it.
- Productivity is still lower than the country average of 450 kg/ha and has missed the targeted 850 kg/ha in 2015[2] but some farmers are reporting large growths in their harvests.[3]
- 81% of farmers report that traders do NOT offer different prices for varying levels of quality.
- In 2019/20, farmers reported receiving a minimum or 25 MZN/KG (US$0.04) to a maximum of 60MZN/KG (US$0.09), with most commonly reported price being 50 MZN/KG (US$0.08). As a point of comparison, Malawi set a minimum farmer price for peanuts in 2020 at K480 per KG, or $0.64, which is the equivalent of 46 MZN/KG.[4]
- In comparison in 2018/19, farmers reported receiving a minimum or 25 MZN/KG to a maximum of 75MZN/KG or (US$1.05), with most commonly reported price being 50 MZN/KG.
- As prices this year are basically the same as last year, though last year the best premium was higher (implying a reduced volume of the best quality peanuts), prices do not match inflation, therefore the overall income generation from peanuts is reducing over time as the costs in country increase.
- 69% of farmers state that the price does NOT change even if the moisture level is higher than normal. The balance of farmers (30%) report that traders deducted an average of 2.8 MZN/KG[5] for higher than normal moisture levels.

[2] http://www.icrisat.org/TropicalLegumesII/pdfs/Bulletin-of-the-Tropical.pdf
[3] In 2018, Mozambique's peanut exports were valued at $13.2M, only 0.51% share of the global market. https://oec.world/en/profile/hs92/ground-nuts
[4] https://times.mw/mixed-feelings-on-farm-gate-prices/
[5] Ranged from a minimum of 2 to a maximum of 5.

- In comparison, 82% of farmers state that the price does change if insect damage is higher than normal. 58 farmers indicate that traders deducted an average of 6.2 MZN/KG[6] for higher than normal insect damage.
- 84% of farmers also report that the price does change if the trader finds a higher amount of damaged and/or diseased pods than normal. 61 farmers report that traders deducted an average of 5.5 MZN/KG[7] for higher than normal levels of damaged and/or diseased pods.
- 82% of farmers deliver one quality of peanuts, i.e. they do NOT deliver varying quality peanuts.
    - Out of those farmers (13) that say they do deliver varying quality peanuts, 7 farmers (10%) believe that they deliver “good” quality peanuts, “good” being defined as being paid a higher price than normal.
    - 10 farmers (14%) state that they deliver “normal” quality peanuts, “normal” being defined as being paid the same price that everyone else gets.
    - 9 farmers (12%) report that they deliver “mixed” quality peanuts.
- 39 farmers (53%) report that their domestic consumption and the need to keep peanuts for sowing (57 or 78%) stop them from delivering all “good” quality peanuts.
- 89% of farmers used saved seeds for the next season.
- Only 9 farmers stated that they bought new seeds.
    - Txonca (big & small) and Nametil (small) are the main seeds used, followed by JL24 and Mamane.
    - JL24 and Mamane are more commonly associated with the survey coverage areas, while Nametil is generally used in South and Central Mozambique.
- 93% of farmers intercrop with their peanuts: 78% with cassava (57); 53% with maize (39); 32% pigeon pea (23); and 27% with cowpea (20) – This implies that farmers interplant their peanuts with more than one crop.
- 73% of farmers (53) report that they shell their peanuts to eat themselves; 74% of farmers (54) also report that they shell their peanuts to sell them; 30% of farmers (22) shell their peanuts as needed.
    - 48% (35) use the money from their peanuts to pay for school fees.
    - 58% (42) to buy other food;
    - 18% (13) to cover healthcare costs;
    - 81% (59) to buy other incidentals for the family and/or the house.
- 37% were experiencing insect problems with their peanut pods in storage.
- 66% of farmers had noticed a change in their peanuts from the first month of storage to the last time they are from their stored peanuts, citing color and smell changes that affected the flavor of the nut, which was mainly attributed to insect infestation.
- Once they run out of peanuts, 63% buy them from the market to keep feeding their family.

	2019/20	**2018/19**

[6] Ranged from a minimum of 2 to a maximum of 10.
[7] Ranged from a minimum of 2 to a maximum of 8.

Average farmer household consumes entire harvest	12 farmers 16%	9 farmers 12%
Average farmer household consumes X% of harvest	56% (n=58 farmers)	44% (n=53 farmers)
Average farmer sells X% of harvest	47% (n=22 farmers)	36% (n=35 farmers)
Average that the farmer saves to sow next season[8]	29%	33%
Average number of farmers that had not sold their harvest yet	42 farmers 58%	25 farmers 34%

7.2 Farmer Practices

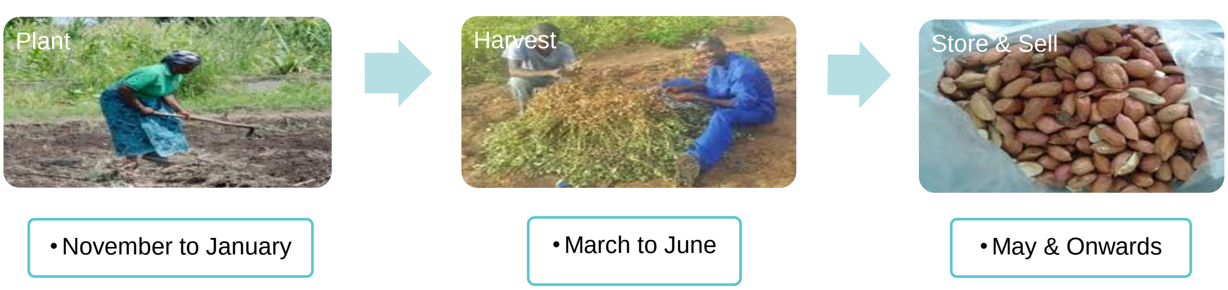
- 49% of farmers report learning about new farming techniques from Technical Service Advisers, while another 49% say that they learn from neighbors and others, i.e. family, farmers associations, their own creativity, etc. Only 1 farmer reported learning anything from the radio.
- Farmers are split in how they initially dry harvested peanut plants and pods – They either stack uprooted plants and pods in ONE heap per row (47%) or ONE heap per FIELD (48%) an average of 2.1 and 2.36 days respectively after they harvest and allow them to dry for an average of 14.36 days directly on the ground confirming the similar finding in 2019.
- 81% of farmers leave their harvest to dry in their unsecured field.
    - This year's data shows (19%) making the effort to move their uprooted peanut plants with pods to a secured location, which is not their field, but this rarely happens the same day that they harvest (2019 data in one district only indicated 13% followed this practice).
- 95% of farmers remove the pod and dry the shell in an unsecured location, such as their field.
- 41% farmers in 2020 reported that they clean and/or sort their peanuts after removing the pods from the plant, farmers take out pods damaged by insects, fungus, disease, or dusty, small, rotten and/or germinated pods. In the 2019 survey, 86% of farmers reported sorting the pods.

[8] 1-(Share of Harvest Ate + Share of Harvest Sold)=Average kept to sow

- 96% of farmers say that this completes their normal drying process for peanut pods, while 3 farmers (4%) continue drying at home.
- Once their pods are dry, 95% of all farmers do NOT shell their peanut pods in the shell immediately after the drying process is completed.
    - This varies from 2019, where 40% shelled immediately after finishing drying.
- While 74% of farmers store their dried peanuts in the shell at home; 10% in a traditional silo; 8% in a silo outside; 8% on their roof to store their peanuts in the shell.
- 95% farmers do nothing else to prepare their peanuts for shelling, while 5% of farmers do remove bad shells, sprinkle the shells with water, or sieve them.
- After shelling, 82% of surveyed farmers then separate good from bad nuts due to nuts being rotten, germinated, small, insect infested, broken, etc.
    - According to the data, 52% of the male farmers surveyed will NOT discard bad nuts versus 18% of female farmers.
    - 79% of farmers that do get rid of bad nuts feed them to their chickens.
- 56% of all farmers store shelled peanuts in polypropylene (PP) bags and 6% will store shelled peanuts in a traditional silo.
- 35% of farmers sell all their shelled peanuts at the same time.
- 96% of all farmers did **not** have **shelled** peanuts in storage.
    - 49% stated that they would keep their pods in storage for an average of 113 days.
    - 37% reported that they were experiencing insect problems with their peanut pods in storage.
    - 66% had also noticed a change in their peanuts from the first month of storage to the last time they are from their stored peanuts, citing color and smell changes that affected the flavor of the nut, which was mainly attributed to insect infestation.

In the ***Storage Experiment***, the 5 participating farmers' stores had the following characteristics:

- 80% (n=4) stores were 30m² or less (one store was 200m²)
- All had metal roofs
- 40% had clay and cement walls, 60% had cement walls
- 100% had cement floors
- 100% had loose food scattered in the store (this will attract rats)
- 100% used the store for other products (casava, rice, cowpeas, pesticides)
- 100% had cleared away rubbish from outside the store
- 40% had a cat to control rats



7.3 Discussion

While prevalence data shows that aflatoxin levels above 10ppb were 35% in 2020 and 39% in 2019, it is not currently a parameter which restricts a trader from purchasing peanuts from a farmer. Peanuts are bought on physical parameters related to color, moisture levels, and damage (both insect and discoloration).

Farmers report that the consumption of peanuts is an important part of their diet, so much so that when their own stocks run out they purchase from the market. They report noting insect infestation and a change in quality of their nuts as they are stored over time.

Hermetic storage will arrest insect damage, and quality changes (as long as the nuts are stored at a suitable moisture level). It appears that farmers are managing to dry their peanuts to a suitable moisture level. Furthermore, hermetic storage has the benefit of arresting aflatoxin development. This means that the peanuts being fed to the family, and in particular to the children, will be healthier.

Work in Kenya showed that farmers adopted hermetic storage for their maize storage because it meant they did not need to use chemicals to prevent insects so they felt that their product was healthier, and they saw that the quality looked better when it was removed from storage. We have not asked farmers in Mozambique whether they treat their peanuts with insecticide, we should in further follow-up investigations.

Finally, work in Kenya also showed that the initial demonstrations of the product are important, but it is more important to look at the supply chain which will deliver the bags to the farmers. If the retailer is not close enough to the farmer to make the product available, the introduction of the technology will fail.

7.4 Annex A: General Results – All Farmers, All Districts

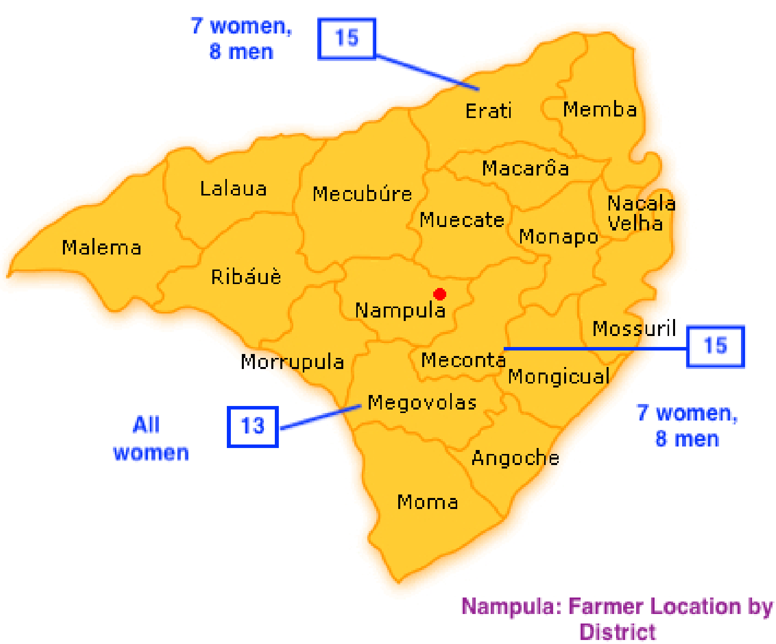
Province	District	Village	Total number pods	Damage incidence by number %	Incidence Insect Damage %	Incidence Broken Pods %	Incidence Mouldy Pods %	Incidence Discoloured Pods %
Cabo Delgado	Namuno	Pambara-Potomola	2233	44	6	3	31	0
Cabo Delgado	Namuno	Pambara-Potomola	2723	14	4	2	4	1
Cabo Delgado	Namuno	Pambara-Potomola	2906	24	3	2	17	0
Cabo Delgado	Namuno	Pambara-Potomola	2244	23	2	1	0	19
Cabo Delgado	Namuno	Pambara-Potomola	2475	34	4	3	24	1
Cabo Delgado	Namuno	Nassupia-Mecuburi	1818	24	3	3	16	3
Cabo Delgado	Namuno	Nassupia-Mecuburi	2819	20	2	1	15	2
Cabo Delgado	Namuno	Nassupia-Mecuburi	2819	33	4	2	19	2
Cabo Delgado	Namuno	Nassupia-Mecuburi	2932	17	2	1	1	13
Cabo Delgado	Namuno	Nassupia-Mecuburi	3211	16	4	1	6	5
Cabo Delgado	Namuno	Milipone-Nacahe	3223	20	3	1	10	6
Cabo Delgado	Namuno	Milipone-Nacahe	2099	17	2	2	7	6
Cabo Delgado	Namuno	Milipone-Nacahe	1511	56	11	4	33	7
Cabo Delgado	Namuno	Milipone-Nacahe	3124	29	2	4	16	5
Cabo Delgado	Namuno	Milipone-Nacahe	2889	26	2	1	16	6
Cabo Delgado	Chiure	Tutua	3434	17	2	1	12	1
Cabo Delgado	Chiure	Tutua	2745	33	1	1	29	2
Cabo Delgado	Chiure	Tutua	2346	11	2	3	0	6
Cabo Delgado	Chiure	Tutua	2815	23	2	1	13	6
Cabo Delgado	Chiure	Tutua	2309	16	3	3	8	2
Cabo Delgado	Chiure	Milamba-Redene	2213	19	6	1	8	4
Cabo Delgado	Chiure	Milamba-Redene	3975	18	5	1	10	1

Cabo Delgado	Chiure	Milamba-Redene	3554	28	7	2	13	5
Cabo Delgado	Chiure	Milamba-Redene	2529	24	10	2	9	3
Cabo Delgado	Chiure	Milamba-Redene	3371	19	6	2	7	4
Cabo Delgado	Chiure	Milamba-Murrenia	3096	33	10	1	14	6
Cabo Delgado	Chiure	Milamba-Murrenia	3898	21	7	1	9	2
Cabo Delgado	Chiure	Milamba-Murrenia	3743	20	8	1	9	1
Cabo Delgado	Chiure	Milamba-Murrenia	3540	29	1	2	12	3
Cabo Delgado	Chiure	Milamba-Murrenia	2628	38	6	2	26	5
Nampula	Erati	Namapa sede-Mucuegera	2271	13	3	1	4	3
Nampula	Erati	Namapa sede-Mucuegera	3309	16	2	1	11	1
Nampula	Erati	Namapa sede-Mucuegera	3324	18	3	3	11	1
Nampula	Erati	Namapa sede-Mucuegera	3032	28	5	2	20	2
Nampula	Erati	Namapa sede-Mucuegera	3714	18	3	2	10	1
Nampula	Erati	Namapa sede-Nacole	3368	28	2	1	21	4
Nampula	Erati	Namapa sede-Nacole	3559	27	2	1	17	6
Nampula	Erati	Namapa sede-Nacole	3685	27	1	1	22	2
Nampula	Erati	Namapa sede-Nacole	3636	28	4	1	16	7
Nampula	Erati	Namapa sede-Nacole	3180	0	5	3	23	4

Nampula	Erati	Alua sede-Nawirimo	2161	41	5	4	3	27
Nampula	Erati	Alua sede-Nawirimo	3265	14	3	0	9	1
Nampula	Erati	Alua sede-Nawirimo	3541	20	4	2	9	4
Nampula	Erati	Alua sede-Nawirimo	3281	23	3	2	12	6
Nampula	Erati	Alua sede-Nawirimo	2940	38	5	3	28	1
Nampula	Meconta	Meconta sede-Teterrene	3613	7	1	1	3	1
Nampula	Meconta	Meconta sede-Teterrene	3679	16	1	1	12	3
Nampula	Meconta	Meconta sede-Teterrene	3862	7	0	1	2	1
Nampula	Meconta	Meconta sede-Teterrene	4063	22	3	2	15	1
Nampula	Meconta	Meconta sede-Teterrene	3240	38	3	3	30	2
Nampula	Meconta	Meconta sede-Morromoto	4596	11	1	2	7	1
Nampula	Meconta	Meconta sede-Morromoto	4643	5	0	1	1	1
Nampula	Meconta	Meconta sede-Morromoto	2937	10	1	1	4	2
Nampula	Meconta	Meconta sede-Morromoto	3518	36	1	6	15	13
Nampula	Meconta	Meconta sede-Morromoto	3649	21	1	1	16	1
Nampula	Meconta	25 de Setembro-Mucuaia	2816	26	2	1	21	1
Nampula	Meconta	25 de Setembro-Mucuaia	2776	45	6	4	30	3

Nampula	Meconta	25 de Setembro-Mucuaia	3900	31	2	0	26	1
Nampula	Meconta	25 de Setembro-Mucuaia	3748	6	0	0	4	2
Nampula	Meconta	25 de Setembro-Mucuaia	2672	92	4	3	67	11
Nampula	Mogovolas	Nametil-Mecupe A	6880	6	0	1	4	0
Nampula	Mogovolas	Nametil-Mecupe A	2961	17	2	0	12	3
Nampula	Mogovolas	Nametil-Mecupe A	3757	25	3	3	12	5
Nampula	Mogovolas	Nametil-Mecupe A	5563	12	1	1	6	2
Nampula	Mogovolas	Nametil-Mecupe A	3377	27	2	2	12	9
Nampula	Mogovolas	Nametil-Mecupe B	3299	27	2	1	18	4
Nampula	Mogovolas	Nametil-Mecupe B	5163	12	0	0	8	2
Nampula	Mogovolas	Nametil-Mecupe B	2551	48	1	2	33	8
Nampula	Mogovolas	Nametil-Mecupe B	4106	16	1	1	13	0
Nampula	Mogovolas	Nametil-Mecupe B	3100	28	1	2	22	2
Nampula	Mogovolas	Nametil-Mecupe C	2399	29	3	1	21	3
Nampula	Mogovolas	Nametil-Mecupe C	3657	32	2	2	19	7
Nampula	Mogovolas	Nametil-Mecupe C	3598	52	1	1	43	5
Nampula	Mogovolas	Nametil-Mecupe C	4730	46	4	4	36	1
Nampula	Mogovolas	Nametil-Mecupe C	6076	31	2	1	26	1

7.5 Annex B: HELVETAS Peanut Farmer Locations



7.6 Annex C: HELVETAS Peanut Farmer Survey Results

General Information	
73	Farmers participated from 5 districts
55%	Of the surveyed farmers were men
45%	Of the surveyed farmers were women
5	Is the median household size (2 adults, 3 children)
82%	Of surveyed farmers report that their children are in school, which is slightly lower than the reported primary education enrollment rate of 94% but may influenced by older children who have a secondary enrollment rate of 19%[9]
75%	Of surveyed male farmers own a mobile phone compared to 52% of female farmers
1.46ha	Is the median farm size
99%	Of surveyed farmers use rainfall as the main source of water for peanut production
Market Information	
81%	Of surveyed farmers say that traders do not offer different prices for varying levels of quality
69%	Of farmers state that the price does NOT change even if the moisture level is higher than normal. The balance of farmers report that they are deducted an average of 2.8 MZN/KG for higher than normal moisture levels.
82%	Of farmers state that the price does change if insect damage is higher than normal. These farmers are generally deducted an average of 6.2 MZN/KG for higher than normal insect damage.
84%	Report that the price does change if the trader finds a higher amount of damaged and/or diseased pods than normal. These farmers are deducted an average of 5.5 MZN/KG for higher than normal levels of damaged and/or diseased pods.
82%	Deliver one quality of peanuts, i.e. they do NOT deliver varying quality peanuts.
Post-Harvest Handling: Drying	
47%	Stack uprooted plants and pods in ONE heap per row an average of 2.1 days after they harvest and allow them to dry for an average of 14.36 days directly on the ground
48%	Stack uprooted peanut plants and pods in ONE heap per FIELD an average of 2.36 days after harvest and allow them to dry for an average of 14.17 days directly on the ground
19%	Of farmers dry their uprooted peanut plants with pods in a secured location, which is not their field. Only 3 farmers (4%) will move their peanut plants with pods to a secured location the same day that they harvest.
95%	Of farmers remove the pod and dry the shell in an unsecured location, such as their field.
36%	Of farmers also dry their peanut plants in other ways, such as using a Dryer Type "A"(54%)[10]

[9] http://uis.unesco.org/en/country/mz
[10] See Annex D

Post-Harvest Handling: Sorting/Cleaning	
41%	Of farmers do clean and/or sort their peanuts after removing the pods from the plant removing pods damaged by insects, fungus, disease, or dusty, small, rotten and/or germinated pods
96%	Of farmers say that this completes their normal drying process for peanut pods, while 3 farmers (4%) continue drying at home.
Post-Harvest Handling: Shelling	
95%	Of farmers, do NOT shell their peanut pods in the shell immediately after the drying process is completed and instead leave them in the shell for 30 days.
74%	Of farmers store their dried peanuts in the shell at home. 10% in a traditional silo; 8% in a silo outside; 8% on their roof to store their peanuts in the shell.
95%	Of farmers do nothing else to prepare their peanuts for shelling, while 5% of farmers do remove bad shells, sprinkle the shells with water, or sieve them.
92%	Of surveyed farmers do not dry the nuts again. The rest dry them again for an average of 2.5 days on something.
82%	Of surveyed farmers then separate good from bad nuts due to nuts being rotten, germinated, small, insect infested, broken, etc.
77%	Discard bad nuts and feed them to their chickens
56%	Store their shelled peanuts in polypropylene (PP) bags
35%	Sell all their shelled peanuts at the same time
96%	Did not have shelled peanuts in storage
89%	Had peanut pods in storage at the time of this survey.
49%	Of farmers would keep their pods in storage for an average of 113 days.
37%	Were experiencing insect problems with their peanut pods in storage
66%	Of farmers had noticed a change in their peanuts from the first month of storage to the last time they are from their stored peanuts, citing color and smell changes that affected the flavor of the nut, which was mainly attributed to insect infestation.

7.7 Annex D: Example of Dryer Type “A”