Technological and Market Interventions for Aflatoxin Control in Ghana: Preliminary Findings

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1 Introduction

Food safety attributes are often unobservable to consumers, especially in informal markets and for products with low traceability. In informal markets, branding is rare and consumers do not always return to the same vendor. Because of the large number of producers and intermediaries, retailers and consumers do not know where agricultural products come from nor the conditions under which they were produced (Hoffmann and Gatobu, 2014; Fafchamps, Hill, and Minten, 2008). Testing is expensive and complicated when food safety threats can occur at multiple points in the production process (Unnevehr, 2000), and certification requires substantial institutional capacity and comes at a potentially prohibitively high cost in developing countries (Auriol and Schilizzi, 2003). This lack of transparency leads to information externalities as described by Akerlof (1970) which in turn results in low quality products available at market, at least along the lines of attributes not observable at the time of purchase. One such dimension is the level of aflatoxin present in foods.

Aflatoxins are a class of mycotoxins, which are toxins produced by fungi. They are tasteless, odorless, invisible, and cause a number of serious health problems if consumed in high quantity (either at one time or over a long period of time). Among other crops, aflatoxins are found in groundnuts and maize, staple crops in much of Africa. Much contamination by aflatoxin occurs from harvest to storage, and groundnuts that are not adequately dried and/or exposed to pests are particularly susceptible (Hell, Cardwell, and Poehling, 2003; Strosnider et al., 2006; Lamboni and Hell, 2009). There are many simple practices farmers can do to prevent contamination, yet adoption of these practices in Africa is low for several apparent reasons: 1) farmers (and other actors along the value chain) know little about aflatoxin and its preventions (Florkowski and Kolavalli, 2013; Jolly et al., 2009; Wagacha and Muthomi, 2008), 2) materials for aflatoxin prevention are not available or expensive, and 3) the market does not reward produce low in aflatoxins (Hoffmann et al., 2013; Hoffmann and Gatobu, 2014).

We employed a randomized controlled trial among groundnut farmers in northern Ghana that tests and compares the effectiveness of two interventions to improve farmer post-harvest practices and reduce aflatoxin: distribution of free drying tarps and a 15 percent price premium conditional on low aflatoxin. Recipients of both treatments also received information about aflatoxin, the risks to human and animal health it imposes, and ways that it can be prevented through better post-harvest groundnut management. Our goal was to find out if simple technologies would be adopted by farmers even in the absence of market incentives or if market incentives were needed to induce adoption. We find positive effects of both interventions on post-harvest practices. Furthermore, we find heterogeneous treatment effects by gender, mirroring differential access to agricultural inputs by gender. The results on aflatoxin are muted, reflecting overall extremely low levels of contamination in the region during end-line data collection.

2 Background

2.1 Aflatoxin in Sub-Saharan Africa

Aflatoxins are secondary metabolites of the fungi *Aspergillus flavus* and *A. parasiticus* that can contaminate many foods, most importantly maize, groundnuts, tree nuts, and cottonseed (Payne, 1998). These toxins have a number of negative health consequences for humans. They are known to increase the risk of liver cancer (IARC, 1993), especially for those with hepatitis B and C (Turner et al., 2003). They have also been shown to exacerbate the effects diseases such as HIV/AIDS and malaria, and to impair physical and cognitive development in children (Gong et al., 2003, 2004). Acute exposure to high doses of aflatoxin, or aflatoxicosis, can cause reduced liver function, poor blood clotting, jaundice, and other problems, and in extreme cases can be deadly, as was the case during several years of outbreaks in 2004, 2005, and 2006 in Kenya resulted in over 150 deaths total (Wagacha and Muthomi, 2008). Aflatoxins affect livestock similarly to how they affect humans, which results in low animal productivity. Furthermore, humans who consume meat or milk from livestock with high levels of aflatoxins also ingest these toxins (Keyl and Booth, 1971; Diekman and Green, 1992; Iqbal et al., 2014).

Aflatoxins are particularly problematic in developing countries, especially in Sub-Saharan Africa, for several reasons. High temperatures and late rains lead to the proliferation of fungi and aflatoxin production (Wagacha and Muthomi, 2008; Wu and Khlangwiset, 2010). Poor production, harvest, handling, and storage practices– largely due to a lack of knowledge (Wagacha and Muthomi, 2008; Florkowski and Kolavalli, 2013; Jolly et al., 2009; Wagacha and Muthomi, 2008)– also contribute to high aflatoxin levels. Poor infrastructure and low levels of technology in developing countries make it difficult to use the same system of standards used in developed countries to limit mycotoxin consumption (Wagacha and Muthomi, 2008; Wu and Khlangwiset, 2010). Standards do exist in some African countries. For instance, in Ghana the official limit for aflatoxin in maize and groundnuts is 15 PPB (Masters, Daniels, and Sarpong, 2013), and in Kenya it is 10 PPB (Hoffmann et al., 2013), compared to 4 PPB in the EU and 20

PPB in the U.S. However, such standards are practically never enforced in domestic markets (Wagacha and Muthomi, 2008; Wu and Khlangwiset, 2010; Masters, Daniels, and Sarpong, 2013) and would not affect food produced for household consumption or local informal trade, which accounts for a substantial amount of production.

Characteristics of consumers themselves make aflatoxin particularly threatening in Sub-Saharan Africa. In this region people, maize and groundnuts are consume dietary cornerstones, and people produce and consume large quantities of maize and groundnuts relative to other foods. In Ghana, 80 percent of people consume groundnuts at least once per week (Jolly et al., 2009). Furthermore, as mentioned in the previously, those in poor health otherwise are more negatively affected by aflatoxin consumption.

2.2 Aflatoxin prevention

Because aflatoxin cannot be destroyed, neutralized, or removed using heat or chlorination (Galvez et al., 2003), preventing contamination is the only way to ensure aflatoxin-safe food. Prevention, or risk reduction, can occur at several stages. During the pre-harvest stage, biological agents to reduce toxigenic molds (Wu and Khlangwiset, 2010). Typically, these agents are atoxigenic strains of *Aspergilli* that outcompete toxigenic strains to colonize the crop. The atoxigenic strains are put in a mixture used to coat some seeds before planting. This type of biocontrol costs be- tween $10-20 per acre, and is most effective when done by a trained professional. Thus, costs and a lack of availability are limiting factors for adoption. Recently, the International Institute of Tropical Agriculture (IITA) and the Consultative Group on International Agricultural Research have developed aflasafe^{TM}, a biocontrol product that is hand tossed on the field 2-3 weeks before crop flowering. A single application is effective for several years for various crops, and therefore offers a potentially easier and cheaper biocontrol method than treating seeds (of Tropical Agriculture, 2016). However, aflasafe^{TM} has not yet been developed for use in all countries, including Ghana; a special product is required for each country that uses local (as opposed to the current Nigerian) strains of atoxogenic *Aspergilli* (of

Tropical Agriculture, 2016).

During the post-harvest stage, there are many relatively simple practices to prevent the spread of aflatoxins. Controlling humidity is essential, and can be achieved by thoroughly drying the crop before storing it, and making sure the storage area is well aerated and kept at a cool temperature (Strosnider et al., 2006; Turner et al., 2005; Udoh, Cardwell, and Ikotun, 2000). Using new storage containers (usually woven plastic or jute bags) or cleaning containers before each use reduces the possibility that mold spores or insect eggs will be introduced during storage. Because damaged nuts are more susceptible to mold, pest control is important (Hell, Cardwell, and Poehling, 2003; Lamboni and Hell, 2009). Applying insecticide in the storage area is therefore an effective (but costly) method of aflatoxin prevention. Sorting out damaged or moldy nuts throughout the drying and storage process is highly effective at preventing aflatoxin (Wu and Khlangwiset, 2010). While this does result in a lower yield, it also results in higher average observable quality (less moldy and broken nuts) and lower aflatoxin risk. While the costs of the components of an effective post-harvest prevention strategy vary, they can be expensive. The package used in Turner et al. (2005) costs $50 per household for an average of 1.25 MT of production.

It is possible for people who consume food contaminated with aflatoxin to reduce their health risks. Enterosorbents are substances that absorb aflatoxin in the gastrointestinal tract. They can be mixed into food or taken as a pill. NovaSil, a type of clay, is an enterosorbent that has been the subject of extensive study and has been shown to effectively bind aflatoxin in humans and livestock (Phillips et al., 2008). While effective, for NovaSil to reduce aflatoxin risk it must be taken with any meal that may contain aflatoxin, which would typically be with every meal for a typical African diet. In addition to the cognitive cost imposed by using NovaSil, there is a high monetary cost; a daily dose may cost less than one dollar (Wu and Khlangwiset, 2010), but this amounts to over $300 per person, per year. Furthermore, without substantial demand it is unlikely markets would develop to get NovaSil to potential users.

Given the relatively low cost and high availability of technologies for post-harvest prevention in Ghana, that is the focus of our study. The information disseminated at our interventions focus solely on harvesting and post-harvest technologies, and our technology handout is drying tarps.[1]

2.3 Aflatoxin testing and detection

One of the many reasons why implementing and enforcing standards for aflatoxin in developing countries is the high cost and difficulty of testing (Zheng, Richard, and Binder, 2006). Rapid quantitative tests (ELISA, fluorometric assay) give a numeric value for aflatoxin content, and require a reader costing upwards of $4000. Test kits cost upwards of $6 per sample. Rapid qualitative tests (lateral flow tests, flow-through immunoassay) do not require expensive equipment, and costs upwards of $4 per sample. New detection methods that are cheaper and more portable are starting to come out. The International Center for Agricultural Research in the Semiarid Tropics is developing a competitive ELISA (cELISA) test they claim costs $1-2 per sample (ICRISAT, 2009; Wu and Khlangwiset, 2010), and Helica has developed a similarly priced test (personal communi- cation with Samuel Mutiga, March 17, 2016). In the early stages of development are “AflaGoggles”, a system that will allow for rapid visual assessment of aflatoxin levels (Yao and Burger, 2014).

Note that these prices are for material alone. All of these methods require skilled technicians, which are in short supply in rural areas of developing countries. In an environment where most trade is informal and for small quantities, aflatoxin testing is prohibitively costly.

[1] Plastic tarps was the technology chosen after conducting a controlled technology trial of multiple simple and cost effective post-harvest technologies aimed at reducing aflatoxin contagion. This trial took place in 2014 and included a non-random sample of 38 generally progressive farmers in both the Upper East and the Northern regions in Ghana. We compared several options highlighted in the literature such as drying racks, pallets and different types of new bags (jute and plastic).

For testing and standards to be possible, a system of contracts and price premiums between farmers and wholesalers, who would test production and get it certified, is necessary. No such system exists for groundnut (or maize) production in Ghana to our knowledge. For our study, we tried to simulate such a system for farmers via are market intervention, which we discuss in detail below.

3 Experimental design

3.1 Study area and sample

Groundnuts are a cornerstone of the Ghanaian agriculture and food industry. They provide income to farmers and multiple nutrients for consumers[2] throughout the country (Florkowski and Kolavalli, 2012). Over the past decade, Ghana has produced an average of 500,000 MT of groundnuts annually (FAOSTAT, 2016), the tenth most worldwide. Most of the Ghanaian population, around 80 percent, consume groundnut or groundnut products at least once a week (Jolly et al. 2008). Afla- toxin (a specific mycotoxin) exposure is perhaps the most daunting food safety challenge facing agriculture in Ghana (News, 2013), and groundnuts are particularly susceptible.

Groundnut production and consumption are especially high in northern Ghana, which is the site of our study. Over 80 percent of national groundnut production occurs in the Northern Region (Tsigbey, Brandenburg, and Clottey, 2003), which accounts for the majority of land in northern Ghana and thirty percent of the country's total land area. The other region in which our study took place is the neighboring Upper East region, which is about one-eighth the size of the Northern Region. Northern Ghana is dry, with a single rainy season. In Northern Region the rainy season goes from April or May to September to October, and in Upper East Region it goes from May or June to October. It is during this time that groundnuts, as well as most other crops, are cultivated.

Our sample consists of a total of 1005 farmers selected from 20 villages in Northern Region and 20 villages in Upper East Region. In each region, we selected four villages each from the

[2] Groundnuts contain high levels of fats, proteins dietary fiber, potassium, magnesium and iron.

closest districts (the geographic unit below the region) to our bases of operation (Tamale in Northern Region and Navrongo in Upper East). Within each district, we selected villages at random that satisfied three criteria. First, we only included villages where a large proportion of households grow groundnuts according to the Ministry of Agriculture. Second, we only selected from villages with between 100 and 300 households so that villages were large enough to ensure there were at least 25 groundnut producing households, but small enough so that we could conduct a census of the village from which to sample households. Third, we included only villages within two hours of a base of operation to limit costs. In each village, we selected 25 groundnut farming households from the village census. Surveys were conducted with a household member who was actively involved in groundnut farming and post-harvest activities.

3.2 Timeline

Fieldwork for this study took place from December 2014 to January 2016. In December 2014 (Northern Region) and January 2015 (Upper East) we conducted a baseline survey and collected groundnut samples from storage for aflatoxin testing. In July (Northern Region) and August (Upper East) 2015, approximately two months before their respective groundnut harvests, we conducted our interventions. In September (Northern Region) and October (Upper East) 2015 we conducted a series of post-harvest observational surveys and visits. Finally, in December 2015 (Northern Region) and January 2016 (Upper East) we conducted an end-line survey and again collected groundnuts samples for aflatoxin testing. Details about the intervention and data collection follows.

3.3 Interventions

Aflatoxin prevention methods have costs and benefits. The costs include materials (drying tarps, storage pallets, pesticides, etc.), added labor, and information search costs. Benefits include higher yields, making it easier to find a buyer, potentially receiving a higher price, and improved health outcomes from groundnuts consumed at home. The goal of this project is to compare the effectiveness in providing farmers with free aflatoxin prevention technology, which lowers the costs, to offering them a market incentive to produce groundnuts low in aflatoxin, which increases the benefits. Given that farmers universally do not know what aflatoxin is, both of these interventions were accompanied by an information session where farmers learned about aflatoxin, its consequences, where it comes from, and how to prevent it. To isolate the effects of technology provision and a market incentive from the effects of information, we include a treatment group that receives only information. Lastly, we include a pure control against which to compare all three of our treatment groups. To maximize statistical power, we assigned treatment at the household level and stratified our sample along several outcome variables of interest to ensure balance across treatment and control groups (see Appendix 1 for details).

3.3.1 Information session

Roughly two months before harvest, members of all three treatment groups participated in an information session. The day before the session, enumerators extended personal invitations to these households. Every effort was made to get the respondent from the baseline survey to attend. If this was not possible, the available household member most knowledgeable about groundnut production was invited. At the time of invitation, the enumerator asked the farmer whether or not he planted groundnuts, how the season was progressing, and what quantity of groundnuts he expected to harvest. This last question determined how many tarps the farmer would receive if he were to be selected for the free technology treatment group. If the respondent was not expecting to harvest any groundnuts, a household member who was expecting a groundnut harvest was invited to the information session.

A trained agricultural extension agent conducted the information session from a script, and presented a short video production, shown on a tablet. The agent first explained the health ramifications of consuming groundnuts contaminated with aflatoxin, and where aflatoxin comes from. He made clear that contamination cannot be eliminated through cooking or processing groundnuts, besides pressing them for oil and disposing of the cakes. He then explained proper (and improper) practices for aflatoxin reduction during harvest, plucking (removing pods from vines), drying, and storage. The specific practices covered in the training can be found in Appendix 2.

At the conclusion of the information session participants drew numbers to assign them to one of three treatment groups: information only, information and free technology (tarps), and information and a market premium. The three groups were physically separated, and within each group farmers took a pictorial quiz on post-harvest practices to reduce aflatoxin and then reviewed the correct answers with a research team member. Then participants in the technology group were given tarps and participants in the market premium group were instructed on how and when they could have their production tested and sell it at a 15 percent price premium. All three groups were given an opportunity to purchase tarps at a reduced price near their village (drastically reducing transaction costs) at a later date. These treatments are described in more detail in the subsections to follow.

3.3.2 Free technology (lowers cost)

Farmers in the free technology group were given as many tarps as needed to dry their projected groundnut production. We wanted to ensure farmers in this treatment group could dry all of their groundnut production on tarps so they would not later mix groundnuts dried on tarps with groundnuts dried elsewhere, which could dilute treatment effects on aflatoxin levels, or result in tarp-dried nuts being infected by other nuts. We also did not want to give any farmers more tarps than needed to reduce the likelihood they would give or lend tarps to others, potentially resulting in spillover effects. Due to supply constraints, we limited the number of tarps a single farmer could receive to six tarps. After farmers were given their tarps they were again reminded of how using the tarps, along with other practices, can prevent aflatoxin-producing molds from growing on their groundnuts.

3.3.3 Market premium (increases benefits)

In Ghana there is very little aflatoxin testing, and in northern Ghana there is none.[3] Therefore, to provide a monetary incentive we needed to create a "market"' for aflatoxin-safe groundnuts. At the conclusion of the information session, a research team member explained to farmers in the market premium treatment group that there is increasing demand in Ghana for groundnuts and groundnut products with low-levels of aflatoxin. Therefore, certain groundnut buyers are willing to pay a premium for groundnuts with low levels of aflatoxin because they can sell these groundnuts into new markets for higher prices. The team member then explained that we were working with such buyers, and would pay 15 percent above the prevailing market price for groundnuts that meet the Ghanian national standard of 15 PPB or less.

Based on a market survey conducted the previous year, we set the purchase date to be 2-3 months after the groundnut harvest, which is also the time we conducted the end-line survey for

[3] To our knowledge, the testing facility we established as part of this study was the first in northern Ghana

the study. Farmers in this treatment group would be reminded of the opportunity to sell to our buyer shorty after harvest as part of a post-harvest visit. They would also be called several days before our buyers arrived. The test would be performed in the village at the time of sale, and farmers shown the result indicating whether or not the buyer would purchase the groundnuts at the premium price. The farmers were then walked through a table that showed what the premium price would be for various market prices. For many farmers in northern Ghana, groundnuts act as a bank account from which they take out small amounts to sell when they need money. For this reason, we wanted to offer farmers greater flexibility for when they sold their groundnuts. We told them that if they decided they wanted to sell at a later date they could call our buyer, who would return to the village to test and purchase groundnuts.[4]

3.4 Opportunity to purchase tarps

At the conclusion of the information session, farmers were told that they could purchase tarps similar to the ones we gave out at a price of 10 GHC (around US$ 3). This was the price at which tarps could be purchased in Tamale, the regional capital and commercial center. Tarps were not observed for sale in any of the villages or nearby towns. These tarps would be available for purchase between one and two weeks after the session, and farmers would be notified of the day ahead of time. On that day, tarps would be available all day on a cash and carry basis. Participants were given a non-transferable coupon for tarp purchase, and were told that the tarps were available for sale to study participants only. All transactions were recorded, as tarp purchase is an important outcome of interest as it demonstrates willingness to invest in better post-harvest practices.

[4] Despite this offer to increase flexibility, most farmers were actually not interested in selling either at end-line or at a later point. In fact only 5 percent of all farmers in the market premium treatment group ended up selling groundnuts to the project team during end-line, as will be shown in the Preliminary Results section.

4 Data

Data collection occurred in several steps structured around our interventions. We conducted a baseline survey in December 2014-January 2015, a post-harvest observational visit and survey in September-October 2015, and an end-line survey in December 2015-January 2016. At baseline and end-line we tested groundnut samples for aflatoxin. In the remainder of this section we describe these stages of data collection and present some descriptive statistics for our sample.

4.1 Baseline survey

4.1.1 Respondent selection

Upon arriving at a selected household enumerators asked for the member who harvested the most groundnuts in 2014 and still had some groundnuts in storage. If this person was not available, the enumerator asked to speak with another member who harvested groundnuts in 2014 and still had some in storage. If no adult household members grew groundnuts and had some in storage, a replacement household was selected from a list. This respondent answered all questions about groundnut production and marketing. For questions on food consumption, the enumerator interviewed the household member most responsible for food preparation.

4.1.2 Descriptive demographics

According to the data collected during baseline: only 39 percent of farmers in the sample had electricity in their homes, 89 percent practiced open defecation, and 59 percent lived in homes with simple dirt floors. The average household size was five, and the average cultivated farm size was 6.6 hectares. The main respondent was the household head 70 percent of the time and the spouse of the household head 18 percent of the time. 68 percent of all respondents where male while 79 percent of all household heads were male. The survey showed a very low level of literacy among the main respondents (14 percent). 94 percent of all main respondents declared that their main occupation was working on their own farm, followed by being an unsalaried non-agricultural worker (3 percent). In terms of their role in groundnut production, 64 percent of the main respondents declared being the primary decision makers for their entire households while 36 percent stated being only the primary decision makers for their own plots. In the case of the male respondents, these percentages were 75 percent and 25 percent while for the female respondents they were inverted to 39 percent in charge of all household decisions vs 61 percent only in charge of their own plot. Finally, 85 percent of all main respondents declared have worked in groundnut productions for more than 5 years with an average experience of 15 years in groundnut production.

4.1.3 Descriptive groundnut production and marketing

The primary variety of groundnut cultivated in 2014 was the China variety (86 percent) followed by Aban (10 percent). 1.88 acres was the average size of land used for groundnut cultivation, with a minimum of 0.2 acres and a maximum of 30 acres of cultivated land. Many respondents expressed that the timing of uprooting was affected by labor availability (24 percent). On average the respondents waited 2.4 days after uprooting the first groundnuts before they plucked the pods from the stems. After plucking, most respondents (71 percent) took the groundnuts to their compounds to dry them on the floor, while 26 percent dried them on the compound roof and only 3 percent left them at the field to dry. It is interesting to notice that only around 1 percent of respondents indicated that they use tarpaulins as the surface to dry groundnuts, while most of them dried them on dirt (59 percent) with the remaining 40 percent of farmers drying either on a rooftop or a bare concrete floor. On average people dried 5.3 non rainy days with over 90 percent of farmers drying 7 or less days. Almost 54 percent of main respondents sorted their groundnuts by quality after drying and 20 percent sorted by mold content. In terms of what the farmers chose to do with the worst of their moldy groundnuts, the practices varied widely across regions. Only 5 percent of main respondents answered they dispose of the worst groundnut in Upper East in contrast to over 29 percent in the Northern Region.

The average production of groundnuts in 2014 for the main respondent was 5.8 Jute bags (also known as Cocoa bags, which can store up to 75 kg. For the household as a whole the average groundnut production was 8 jute bags. 64 percent of the main respondents produced at least 80 percent of the household groundnut production. Over 99 percent of main respondents store groundnuts in either plastic sacks (72 percent) or Jute sacks (27 percent). Similarly, over 44 percent use new brand containers. 98 percent of the respondents stated they store their groundnuts in their house. When asked about the surface they store the groundnuts on 78 percent responded on wooden pallets, 13 percent directly on the concrete floor and 6 percent directly on the dirty floor. Most farmers (73 percent) never treat or disinfect their storage facility before storing newly harvested groundnuts.

Farmers responded they only sold groundnuts in shells (dry) and groundnuts in kernels (dry). None of the respondents expressed selling either moist groundnut shells or roasted groundnuts. Hence all the following statistics are for dry groundnuts in shell and dry groundnut kernels. Farmers obtain groundnut price information from either the market (63 percent) or family and friends in the village (21 percent). Their main buyer are market ladies (57 percent), followed by local traders (25 percent) and village retailers (13 percent). Most farmers (77 percent) said that the buyer is not the same each year. Farmers arrange the sale of their products in various ways. 33 percent bring their groundnuts to the market and look for a buyer, 16 percent said a known buyer visits them for immediate purchase, similarly 16 percent said an unknown buyer visits them for immediate purchase. Finally 14 percent responded that a buyer visits them in advance for sale. The most common place to sell groundnuts is at home or at the farm (55 percent), followed by the local market (40 percent) and finally the Regional market (5 percent). The distance from home to the point of sale is less than 5 miles in 90 percent of the cases and 97 percent of the respondents stated that it costs them 10 GHc (around US$ 3) or less to get to the point of sale. Finally, farmers said that most buyer do inspect the groundnuts for quality before buying it (86 percent). Also they said that they receive in general a lower price for moldy groundnuts (76 percent).

4.1.4 Groundnut sampling and aflatoxin levels

At the conclusion of each survey, the enumerator asked to purchase a small sample of groundnuts for aflatoxin testing. When applicable, separate samples were taken for groundnuts intended for sale and groundnuts intended for home consumption. The enumerator took a sample representative of all groundnuts in storage intended for each use by randomly choosing bags to pull groundnuts from, and pulling groundnuts from multiple locations within each sampled bag. Samples were then taken to a laboratory, ground, and tested for aflatoxin using fluorometric assays.[5]

Only 979 out of the 1005 farmers interviewed agree to let the enumerator observe his/hers store groundnuts. The main reason why observation was not allowed was that there were no groundnuts in storage (73 percent) followed by the storage unit not being accessible (28 percent). At baseline, 72 percent of farmers planned to sell at least some of the stored groundnuts. 920

[5] FluoroQuant reader and kits from Romer Labs, Union, MO.

samples were collected from the stored nuts. 195 samples were taken of groundnuts exclusively intended for sale, 648 samples of groundnuts intended exclusively for home consumption and 207 from mixed samples. The average aflatoxin concentration level (measured in ppb) at baseline was 63.1 ppb, with 44.4 ppb for sample destined exclusively for sale and 89.8 ppb for the sample destined exclusively for home consumption.

4.2 Post-harvest observation

Coinciding with the groundnut harvest we conducted a short visit and survey with all households. This survey was done mainly to observe the most critical period of production with respect to aflatoxin prevention. In addition, the survey included reminders about best practices for treatment farmers only. Enumerators attempted to reach farmers during the week-long drying period to observe the drying surface, ask about the length of drying, and inspect the storage area. The enumerator also asked questions about activities leading up to storage: harvest timing, length of time between uprooting and plucking, sorting out of bad nuts before drying, and tarp purchase or possession. If the farmer had not yet begun drying, the enumerator returned up to two additional times.

4.3 End-line survey

From the original 1005 main respondents in the baseline survey, almost 97 percent (972 farmers) were found the next year when the intervention took place. The attrite sample (33 farmers) includes farmers that migrated, that did not produce groundnuts in 2015 or could not be found at all. After the randomization 247 main respondents were assigned to the control group and 725 to one of the treatment arms[6]. Since around 15 percent of the original main respondents from the baseline survey were replaced by other household members that attended the trainings, now onwards we will referrer to them as the intervention attendees. During the end-line survey the enumerators were asked to collect information from the intervention attendees, for all the households were a farmer was assigned to a treatment arm.[7] Of the 247 households in the control group, 225 of the main respondents from the baseline survey were interviewed during the end-line survey. For the treatment arms 675 out of 725 households that attended the interventions sessions were found and interviewed during end-line (210 belonging to the information only treatment group, 256 to the technology arm group and 209 to the market premium treatment arm).[8]

The end-line survey contained many of the same questions about groundnut production, post-harvest practices, marketing, and consumption as the baseline survey. In addition, there were several questions about tarp purchase and use. At the conclusion of the survey, enumerators either purchased groundnuts (per the agreement with the market premium treatment group) or purchased a sample of groundnuts for aflatoxin testing. Because testing needed to be done at the point of sale for the market premium treatment group[9], we used a mobile rapid testing procedure

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[6] The individuals that were assigned to one of the treatment arms received training, technology in the form of tarps or / and the option to receive a market premium if their groundnuts tested below the level considered aflatoxin safe according to Ghanaian authorities (<15 PPB).

[7] Only if they could not get in touch with this person after attempting to reach them repetitively, the enumerators should collect information from the baseline main respondent. For the households that belong to the control group, information should be collected from the baseline main respondent.

[8] Over 99 percent of the farmers that belonged to a treatment arm and that were interviewed at end-line in were intervention attendees.

[9] This procedure was necessary since our intervention could potentially generate an incentive for farmers in this treatment group to sell us their "best" groundnuts and keep the most contaminated for home consumption. We needed to find out at the moment of the survey if that was the case, in order to trigger a safety protocol to replace

for all farmers at end-line.[10]

4.3.1 Descriptive groundnut production

The primary variety of groundnut cultivated in 2015 was still the China variety (78 percent) followed by Aban (16 percent). 1.96 acres was the average size of land used for groundnut cultivation, with a minimum of 0.25 acres and a maximum of 12 acres of cultivated land. Many respondents expressed again that the timing of uprooting was affected by labor availability (22 percent). However, drying practices changed dramatically across survey rounds. At end-line half (50 percent) of farmers dried their groundnuts on a rooftop or a bare concrete floor, while 26 percent of respondents indicated that they use tarpaulins as the surface to dry groundnut and only 24 percent of respondents dried their groundnuts on dirt. Similar to baseline, on average people dried 5.2 non rainy days with 79 percent of farmers drying 7 or less days. 67 percent of respondents sorted their groundnuts after drying. Again, practices varied widely across regions when it came to what farmers chose to do with the worst of their moldy groundnuts, but in both regions the percentage of "bad" groundnuts disposed of increase. 11 percent of respondents answered they dispose of the worst groundnut in Upper East in contrast to 33 percent in the Northern Region.

The average production of groundnuts in 2015 for the respondent was 5.9 Jute bags. Almost 64 percent of main respondents store groundnuts in plastic sacks or 36 percent in Jute sacks. Similarly, over 51 percent use new brand containers. When asked about the surface they store

highly contaminated groundnuts destined to home consumption. As it happens we only encounter once the case where we needed to trigger the safety protocol.

[10] Neogen test strips (Neogen, Lansing, MI) and Mobile Assay strip reader (Mobile Assay, Boulder, CO).

the groundnuts on 79 percent responded on wooden pallets and 12 percent directly on the concrete floor. Finally, there was an important change in the percentage of farmers that treat or disinfect their storage facility before storing newly harvested groundnuts. This percentage increased from 27 percent at baseline to 34 percent at end-line.

5 Preliminary Results

Preliminary results reported in this section are based on data collected during the end-line survey. Coefficients from linear regression models, in which outcomes are regressed on treatment indicators and the control group is the excluded category. We present two sets of regressions, the first includes controls for baseline characteristics while the second one has no controls.[11] For simplicity, we describe the impacts of the regressions that include all controls. Yet, the results for both the size of the coefficients and their level of significance are very similar for the estimations with no controls. In addition, we have looked into heterogeneity treatment effects by gender, given the existence of differential access to agricultural inputs by gender in Ghana[12]. These disaggregated results are presented towards the end of this section.

5.1 Post-harvest practices

5.1.1 Drying practices

Table 1 shows the impact of each treatment on reported incidence of drying groundnuts mostly on dirt. While 28 percent of those in the control group reported drying their groundnuts primarily on the bare earth, those in the free tarps group were 19.8 percentage points less likely to report this practice (significant at $p<0.01$), as well as those in the market treatment group, who were 6.8 percentage points (significant at $p<0.10$) less likely to dry on dirt. Impacts on the information treatment on this outcome are close to zero and not statistically significant.

[11] Baseline controls include: literacy, experience, gender, household size, gender of household head, access to electricity, dirt floor, has separate room used as a kitchen, size of land used for groundnut cultivation and the baseline value of the outcome used as the dependent variable.

Table 1: Treatment effects on drying groundnuts on dirt

	All controls included	No controls included
Information	0.034	0.034
	(0.041)	(0.040)
Free tarp	-0.198	-0.189
	(0.039)***	(0.039)***
Market premium.	-0.068	-0.062
	(0.041)*	(0.041)
R^2	0.05	0.03
N	901	901

* *p*<0.1; ** *p*<0.05; *** *p*<0.01

Table 2 shows the impacts on reported tarp use are similar: only 4.4 percent of those in the control group reported drying primarily on tarps, while in the tarp group two thirds of respondents did so. For this outcome, we see a significant impact of information alone (an 8.2 percentage point increase, significant at p<0.05) and an obvious huge effect of being in the free tars group (55.1 percentage point increase, with p<0.01).

Table 2: Treatment effects on drying groundnuts exclusively on tarpaulins

	All controls included	No controls included
Information	0.082	0.084
	(0.034)**	(0.034)**
Free tarp	0.551	0.543
	(0.033)***	(0.033)***
Market premium.	-0.017	-0.019
	(0.034)	(0.034)
R^2	0.37	0.36
N	901	901

* *p*<0.1; ** *p*<0.05; *** *p*<0.01

Having access to information had a positive impact on reported tarp purchases, relative to the control group, 8.4 percent of which reported buying a tarp (note that tarps could have been purchased from other households in the village, directly from the study, or from other vendors - this measure captures all purchases). Table 3 shows that the percentage of households who reported purchasing a tarp in the information group was more than double that in the control (9.1

[12] In particular we will look into access to insecticide, new containers, tarps and key information such as knowing

percentage points higher and significant at p<0.01). . Impacts on free tarp and the market treatment groups on this outcome are small and not statistically significant.

Table 3: Treatment effects on buying tarpaulins

	All controls included	No controls included
Information	0.091	0.097
	(0.035)***	(0.035)***
Free tarp	-0.033	-0.033
	(0.034)	(0.034)
Market premium.	0.044	0.038
	(0.035)	(0.035)
R^2	0.04	0.02
N	901	901

* p<0.1; ** p<0.05; *** p<0.01

Similarly, the information treatment had a positive impact on the total number of reported tarp purchased, as shown in Table 4. On average, the information treatment increase the number of tarps purchased by 0.275 (statistically significant at p<0.01). Given that the control bought on average 0.084 tarps, this is a pretty significant change.

Table 4: Treatment effects on the total number of tarpaulins purchased

	All controls included	No controls included
Information	0.275	0.285
	(0.085)***	(0.084)***
Free tarp	-0.125	-0.116
	(0.082)	(0.082)
Market premium.	-0.006	-0.014
	(0.086)	(0.086)
R^2	0.03	0.02
N	901	901

* p<0.1; ** p<0.05; *** p<0.01

Finally, the number of days spent drying nuts were not affected by any of the treatments, as shown in Table 5. This is not surprising since most farmers at baseline (97 percent) believed they dried their groundnuts long enough.

the importance of not drying groundnuts on dirt.

Table 5: Treatment effects on the number of sunny days groundnuts were dried

	All controls included	No controls included
Information	0.094	0.070
	(0.194)	(0.199)
Free tarp	0.149	0.197
	(0.187)	(0.193)
Market premium.	0.317	0.300
	(0.196)	(0.202)
R^2	0.08	0.01
N	901	901

* p<0.1; ** p<0.05; *** p<0.01

5.1.2 Sorting practices

As shown in Table 6, while all treatments increased the proportion of farmers who report sorting their groundnuts by hand prior to storage, only the information treatment has a statistically significant impact on this outcome. While 34 percent of those in the control group reported hand sorting after drying, those in the information group were 12.4 percentage points more likely to report this practice (significant at p<0.01).

Table 6: Treatment effects on groundnuts being sorted by hand picking after drying

	All controls included	No controls included
Information	0.124	0.120
	(0.048)***	(0.047)**
Free tarp	0.027	0.022
	(0.046)	(0.046)
Market premium.	0.018	0.019
	(0.048)	(0.048)
R^2	0.04	0.01
N	901	901

* p<0.1; ** p<0.05; *** p<0.01

In contrast, the proportion who reported discarding bad groundnuts is increased by being part of both the information and the free tarp group. Table 7 illustrates the impact of both these treatments. Only 14.7 percent of those in the control group reported disposing of the worst groundnuts, while in the tarp group 28.1 percent of respondents did so. For this outcome, we see a significant impact of information alone (a 7.4 percentage point increase) and an effect of being in the free tars group of 6.7 percentage point (both effects significant at p<0.10).

Table 7: Treatment effects on disposing of worst groundnuts

	All controls included	No controls included
Information	0.074	0.077
	(0.039)*	(0.039)**
Free tarp	0.067	0.057
	(0.037)*	(0.038)
Market premium.	-0.030	-0.033
	(0.039)	(0.040)
R^2	0.08	0.02
N	901	901

* *p*<0.1; ** *p*<0.05; *** *p*<0.01

5.1.3 Storage and marketing practices

In Table 8, we see evidence that both the free tarp and the market treatments increased the chance that farmers adopted recommended disinfecting practices (in contrast with 28 percent of the control). In particular, provision of free tarps resulted led to a 15.9 percentage point increase (p<0.01) in the probability that farmers treated the storage unit with insecticide before storing freshly harvested groundnuts, while belonging to the market treatment group increase the incidence of treating the storage area with insecticide by 9.9 percentage points (p<0.05).

Table 8: Treatment effects on Insecticide treated storage unit

	All controls included	No controls included
Information	-0.013	-0.013
	(0.045)	(0.045)
Free tarp	0.159	0.163
	(0.044)***	(0.044)***
Market premium.	0.099	0.090
	(0.046)**	(0.046)**
R^2	0.05	0.02
N	901	901

* *p*<0.1; ** *p*<0.05; *** *p*<0.01

In contrast, the probability of using new bags for storage, was positively impacted by all treatments but none of them had statistically significantly impacts on the outcome, as shown in Table 9. Yet this is one of the few cases where the estimation without controls shows a statistically significant effect not shown in the estimation with all controls. In the former case, there is a statistically significant effect of belonging to the tarp free treatment group equivalent to a 7.8 percent increase.

Table 9: Treatment effects on storing groundnuts in new containers

	All controls included	No controls included
Information	0.062	0.051
	(0.048)	(0.048)
Free tarp	0.070	0.078
	(0.047)	(0.046)*
Market premium.	0.009	0.019
	(0.049)	(0.049)
R^2	0.03	0.01
N	901	901

* *p*<0.1; ** *p*<0.05; *** *p*<0.01

Only the information treatment had a positive impact on the likelihood that groundnuts were stored on a raised platform or wooden pallets, also a common practice among those in the control group, at 69 percent. The information treatment effect on this outcome was of 11.8 percentage points (significant at p<0.01), as seen in Table 10.

Table 10: Treatment effects on storing groundnuts on wooden pallets

	All controls included	No controls included
Information	0.118	0.125
	(0.039)***	(0.039)***
Free tarp	0.018	0.018
	(0.038)	(0.038)
Market premium.	0.018	0.014
	(0.039)	(0.039)
R^2	0.04	0.02
N	901	901

* *p*<0.1; ** *p*<0.05; *** *p*<0.01

Similarly, only the information treatment had a positive impact on the likelihood that farmers decided to sell their groundnuts at a regional market (in contrast to local markets or at the farm), an uncommon practice among those in the control group, at 3.8 percent. As seen in

Table 11, the information treatment effect on this outcome was of 6.9 percentage points (significant at p<0.10), which is more than double that the mean in the control group.[13]

Table 11: Treatment effects on selling at the regional market

	All controls included	No controls included
Information	0.069	0.063
	(0.040)*	(0.031)**
Free tarp	-0.018	-0.036
	(0.039)	(0.030)
Market premium.	0.012	-0.053
	(0.043)	(0.033)
R^2	0.05	0.01
N	277	510

* p<0.1; ** p<0.05; *** p<0.01

5.1.4 Heterogeneous treatment effects by gender

SECTION STILL IN PROGRESS.

5.2 Aflatoxin levels

Overall, the level of aflatoxin in the study area was very low in 2015. The overall mean contamination level in the study sample was just 3.3 ppb, well below the regulatory limit of 15 ppb, and only 4.6 percent of samples tested above 15 ppb. Similar findings have been documented in samples collected by other research groups. Within this context, the impact on aflatoxin levels of changes in farmer practices, and thus of the experimental treatments are difficult to detect - indeed we see no significant impact in our sample overall.

Table 12 shows results for the overall sample. Because of the skewed nature of the data, we analyze impacts on the natural logarithm of aflatoxin. The point estimate of the information

[13] It should be noticed that the difference in sample size across estimations is due to the absence of the sales information at baseline for some of the observations.

treatments is negative, and the impact of the market incentive and the tarps are positive. However, confidence intervals for all treatments are very large and none of the impacts are significantly different from zero. . It should be noticed that the difference in sample size across estimations is due to the absence of the aflatoxin level at baseline for some of the observations.

Table 12: Treatment effects on log aflatoxin

	All controls included	No controls included
Information	-0.048	-0.060
	(0.118)	(0.115)
Free tarp	0.107	0.106
	(0.110)	(0.109)
Market premium.	0.030	0.078
	(0.118)	(0.116)
R^2	0.05	0.00
N	677	729

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Recalling that farmers in each of the treatment groups (particularly those in the free tarps group) saved more seed than those assigned to control, we also test the impact on aflatoxin separately by the volume of nuts saved as seed. Differential selection into the sampled nuts (which were taken from among those stored for consumption or sale, and excluded those saved as seed) could potentially bias our estimated treatment effects on aflatoxin toward zero if nuts saved as seed had lower levels of aflatoxin contamination.

Splitting the sample this way (Table 13), we indeed see a more pronounced reduction in aflatoxin contamination relative to the control in all treatments among the farmers who saved less than 1 bag (100 kg) of nuts for use as seed. The effect of the free tarps treatment within this subgroup, in the estimation without controls, is significant at the 10 percent level, and quite large, amounting to over 28 percent reduction in the level of aflatoxin contamination.

Table 13: Treatment effects on log aflatoxin by amount kept for seed

	All controls included		No controls included	
	<= 1 bag of seed	> 1 bag of seed	<= 1 bag of seed	> 1 bag of seed
Information	-0.232	0.166	-0.283	0.172
	(0.148)	(0.186)	(0.153)*	(0.171)
Free tarp	0.232	-0.037	0.218	-0.017
	(0.143)	(0.169)	(0.150)	(0.160)
Market premium.	0.141	-0.062	0.222	-0.073
	(0.149)	(0.184)	(0.155)	(0.172)
R^2	0.10	0.05	0.01	0.00
N	332	345	361	368

* p<0.1; ** p<0.05; *** p<0.01

6 Concluding Remarks

Preliminary results of this study, based on data collected through the end-line survey, show that both subsides for technology, and market incentives to produce safe food, lead to significant improvements in the practices of Ghanaian smallholder farmers with respect to aflatoxin management. Importantly, providing a subsidy for tarps on which farmers can dry their groundnuts appears to crowd in other recommended practices: farmers are more likely treat their storage units with insecticide before storing new groundnuts and, marginally, to store nuts in new bags, when they are provided free tarps. Furthermore, the provision of information and the opportunity to buy tarps at a reduced cost had an important effect on other aflatoxin reducing behaviors such as drying groundnuts on tarpaulins, buying more tarpaulins, sorting their groundnuts by hand and disposing of the worst groundnuts prior to storage and storing groundnuts on pallets. In addition, it seems that farmers with access to information felt more empowered to sell their groundnuts in regional markets. We also find heterogeneous treatment effects by gender[14] which are related to differential access to agricultural inputs in Northern Ghana.

Finally, while the impact on aflatoxin in 2015 was muted due to low overall contamination levels in the study region, and an apparent selection of the best groundnuts for use as seed and thus out of the sample, we do see a large and marginally significant reduction in contamination among farmers who stored relatively modest amount of nuts.

[14] These effects will be discussed in detail in the final version of this paper, to be presented at the conference.

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Appendix 1: Stratification procedure

To obtain better balance between treatment and control, we stratify our randomization as follows. First, we generate strata of four households within each village based on aflatoxin levels recorded at baseline. Next, we randomly assign three out of four households to receive treatment and the fourth to control. Which treatment the household received was determined in a public lottery at the end of the information session, and therefore randomization across treatment groups was not stratified. For villages that did not have 20 or 24 farmers, either 20 households (for those with between 21-23 households) or 24 household (for those with more than 24 households) were stratified based on aflatoxin levels. The 1, 2, or 3 remaining households were assigned treatment at random so that no two of these remaining households received the same treatment. Next, we run 1000 re-randomizations to ensure balance along aflatoxin levels and a number of post-harvest practices, which are also outcomes of interest for this study. From these 1000 re-randomizations we eliminate any where the p-value for aflatoxin level was below 0.8. Of the remaining randomizations, we select the one with the maximum minimum p-value following (Bruhn and McKenzie, 2009).

Appendix 2: Information session content

The following is a summary of specific practices covered in the information session organized by production stage.

1. Harvest
    - Harvest when leaves begin wilting and turning yellow.
    - Check inside of ten sample pods to confirm crop is ready for harvest.

2. Plucking
    - Pluck pods from vines as soon as possible after harvesting.
    - Do not leave pods exposed to soil while waiting to pluck.
    - As you pluck, remove and discard visibly damaged pods (shriveled, have holes, broken, moldy, discolored)

3. Drying
    - Dry on a clean surface: use a tarp if possible, or otherwise a concrete slab or rooftop.
    - Do not dry on bare dirt.
    - Dry on a smooth surface that will prevent water from puddling.
    - Avoid breaking pods when spreading them on the drying surface; use a rake, not feet.
    - Sort out visibly damaged pods from the drying area and dispose of them.
    - Protect pods from the rain; either bring them in or cover them with thatch

(traditional) or tarp. Once the rain has stopped, spread them again immediately and dry the covering surface, is applicable.

4. Storage

- Use new bags or clean bags by turning them inside out and laying them out under the sun to kill insect eggs and mold.
- Remove and discard visibly damaged nuts before putting them in bags.
- Remove old stock from storage area before adding new stock.
- Store bags on raised platforms that allow for airflow (locally available or home-made pallets).
- Store bags away from walls of storage area.