Aflatoxin Contamination of Maize in Kenya: Observability and Mitigation Behavior

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Using a unique dataset of maize samples and consumer interviews form Eastern Kenya, we find that the presence of the fungal contaminant aflatoxin is negatively associated with the use of maize flour for food. While food remains the most common use of maize regardless of the presence of the toxin, contaminated maize is relatively more likely to be used for the production of alcoholic beverages, livestock feed, or sale. Retail maize prices are strongly correlated with an easily observable quality attribute, discoloration, but the correlation between price and aflatoxin contamination is not statistically distinguishable from zero. This suggests that consumers observe attributes that are correlated with aflatoxin upon careful inspection, or perhaps consumption of a portion of maize from a particular batch, and that their use of flour is based on this information. The apparently limited observability of attributes associated with aflatoxin contamination implies that problems associated with asymmetric information may affect this market. A comparison of maize quality by source provides evidence of such problems: purchased maize is more likely to be contaminated with aflatoxin than maize households have grown themselves, despite the fact that maize from larger producers is less likely to be contaminated.

JEL codes: O12, O13, O15

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I. Introduction

Contamination of food with fungal toxins is a widespread problem in tropical and subtropical regions and beyond. A particularly dangerous fungal contaminant, prevalent in Kenya, is aflatoxin. Aflatoxin, which commonly affects maize, causes illness and even death when consumed in large quantities. Low-level, chronic exposure is carcinogenic and has been linked to growth retardation in children (Strosnider et al., 2006). Stress while crops are growing, insufficient drying, and poor storage practices increase the likelihood that crops become contaminated (Wilson and Payne, 1994; Hell et al., 2008). Prevalence studies of aflatoxin contamination of maize in Kenya's formal and informal sectors consistently show high average levels of contamination, ranging from 16 to 65 percent of samples testing above the allowable limit for aflatoxin (Lewis et al., 2005; Gathura, 2011; Daniel et al., 2011; Mahuku and Sila, 2011). Given that maize is the primary staple grain for Kenyans, accounting for 36% of total food caloric intake (Kirimi et al., 2011), even relatively low levels of exposure may have significant negative health effects (Shephard, 2008).

While aflatoxin itself is invisible and tasteless, its presence may be correlated with other attributes that facilitate or result from fungal growth, including physical damage to the protective outer layer of the kernel, discoloration, and compromised taste quality. Observation of these attributes may allow consumers to reduce their exposure to aflatoxin by avoiding maize that is likely to be contaminated, or by directing such maize to uses that are less harmful to their health. For example, fermentation of grain to produce beer reduces the level of aflatoxin contamination by up to 82 (Chu et al., 1975). Contaminated grain may also be fed to livestock. This reduces livestock growth and aflatoxin may be present in animal products, but at lower levels than in the grain itself (Bhat et al., 2010).

Whether consumers are able to observe attributes that contain information about food safety prior to purchase has implications both for public health and for the efficiency of this market. More broadly, if attributes that matter to consumers can only be observed after purchase, limited incentives to improve maize on these dimensions will lead to their under-provision. While the effects of information asymmetries could potentially be mitigated through repeated interactions and reputation effects, the structure of the Kenyan maize market does not lend itself to the development of strong reputation effects. An analysis of Kenya's maize marketing system by Kirimi and coauthors (2011) found that smallholder maize is generally purchased by small-scale assemblers or brokers, who aggregate maize for sale on to wholesalers. Wholesalers then transport maize from surplus to deficit regions, exploiting spatial arbitrage opportunities. Finally, disassemblers in destination regions disaggregate this maize into smaller quantities for sale to consumers. The authors observe that the maize assemblers who purchase from farmers "are not very concerned with quality and moisture standards…." and that "the current structure of Kenya's maize market provides little incentive for farmers to produce high quality maize, because quality rarely translates into greater returns when selling through the small-scale assembler marketing channel." (ibid, p. 41)

Other recent work shows that Kenyan consumers value quality attributes that are unobservable through visual inspection alone. Using bids in a second-price auction for maize, Hoffmann and Gatobu (2013) demonstrate that consumers in rural western Kenya were willing to pay 12 percent more for market-sourced maize from which a sample was cooked and offered for tasting prior to bidding than the same maize offered without the opportunity to taste a sample. Willingness to pay for maize that participants had grown and stored themselves was even higher.

Using a unique dataset from in Eastern Kenya, a region of high aflatoxin prevalence, we find that consumers believe the likelihood of experiencing health problems due to consumption of low quality maize is substantial. Data from 1500 customers interviewed at small-scale hammer mills reveal that most took measures to reduce their exposure to low-quality maize: 94 percent of respondents reported sorting grains before milling, with 74 percent of those citing health reasons for doing so. Prices are strongly correlated with easily observable quality attributes. However, aflatoxin contamination may be present in the absence of any visible grain damage, and the correlation between price and aflatoxin is not statistically distinguishable from zero. Contaminated maize, however, is significantly less likely to be consumed as food by household than uncontaminated maize. Such maize is more likely to be used as an input in production of alcoholic beverages, used as livestock feed, or sold. This suggests that consumers observe attributes that are correlated with aflatoxin upon careful inspection, and perhaps consumption, of a sample of maize from a particular batch, and that their use of flour is based on this information.

The apparently limited observability of attributes associated with aflatoxin contamination implies that problems associated with asymmetric information may affect this market. We present suggestive evidence of such problems. First, maize in our sample that has been purchased is more likely to be contaminated than maize households have grown themselves, despite the fact that maize from larger producers is less likely to be contaminated. Other qualities which deteriorate over time are not, however, worse in purchased maize, suggesting that the difference in this unobservable quality is driven by how marketed maize is selected or handled, rather than simply the duration over which such maize is stored. Moreover, among a small supplementary sample of 100 maize farmers, 32% of those who sold maize reported differences in the post-harvest handling of maize destined for sale and that consumed by the household, with more careful drying and storage of maize consumed at home.

The remainder of the paper proceeds as follows. Section II outlines a simple theoretical model of how farm households make decisions about how to store and use grain. The data and empirical strategy for testing the predictions of the model are described in Section III. Section IV presents the empirical results, and Section V concludes.

II. Theoretical framework

Grain quality varies in three dimensions: observable quality o, which is seen by the consumer prior to purchase, experience quality e, observed only after purchase, and unobservable quality u, which does not affect the consumer's experience of the grain but may have long-term health consequences. Each of these three dimensions of quality is positively, but imperfectly, correlated with the other two.

A farm household derives utility from the consumption of grain as food, from non-food purposes to which it may be put, and from the consumption of a numeraire good x. The value of consuming grain as either food or using it for some other, non-food purpose (production of fermented beverages, livestock feed) depends on the product of the quantity of grain used for that purpose, denoted q_f and q_n respectively multiplied by the experience quality of that particular batch of grain:

$$U = U(q_f \cdot e_f, q_n \cdot e_n, x). \tag{1}$$

Utility is impacted more strongly by the experience quality of maize consumed as food than that of maize used for other purposes,

$$\frac{\partial U}{\partial e_f} > \frac{dU}{de_n}. \tag{2}$$

The household maximizes utility subject to an income constraint, which requires expenditures on x, drying and storage inputs, d, and purchased grain not to exceed income. Income is derived from the sale of a quantity of grain q_s at price p_g. Purchase and sales prices depend only on the grain's observable attributes, o_p and o_s, and the time of the transaction relative to harvest, *t*:

$$p_g(o_p, t) \cdot q_p + x \ + d \leq \ p_g(o_s, t) \cdot q_s. \tag{3}$$

An additional constraint states that the quantity of grain harvested, q_h, plus that which is purchased, q_p, minus that sold, q_s , is equal to the sum of the quantity used as food and non-food consumption:

$$q_h + q_p - q_s = q_r = q_f + q_n \tag{4}$$

Grain that is destined for sale may be treated differently from that which is retained for own consumption. The quantity as well as each of the quality attributes of grain retained and stored by the household are each increasing in the resources devoted to cultivation A, and in drying and storage inputs d, and decreasing in time since harvest *t*. Quantity and all three dimensions of quality are subject to a common, mean-one shock e_h, representing climate stress and certain types of pest infestations which affect both quality and quantity, and an idiosyncratic shock e_j, which also has a mean of one:

$$j_k = f_j(A, d_k, t) \cdot \varepsilon_h \cdot \varepsilon_j, \qquad j = q, o, e, u; \quad k = r, s, \tag{5}$$

where s denotes grain destined for sale, and r indicates that which is retained for household use.

The fact that pricing is based only on o implies that unless the correlation between o and e is perfect, farmers will set $d_s < d_r$. If the price of maize is expected to increase over time, there will be an incentive for both store farmers and traders to store maize for sale later in the season up to the point at which the associated reduction in observable quality offsets the intertemporal price advantage. The experience quality of grain available for purchase on the market will thus be lower than that of grain which is retained for home consumption, and the overall quality of grain will be below the social optimum. The positive correlation between e and u implies that the unobservable quality will also be higher in retained than in marketed grain.

Together with concavity of the utility function, equation (5) implies that farmers with a larger endowment of resources to allocate to cultivation, and more favorable yield shocks, who produce more and higher quality grain, will supply a disproportionate share of the market. If identical storage practices are applied to marketed grain as to that which is retained for home consumption, the average unobservable quality of marketed grain should thus be higher than that grown and stored by farmers for the same period of time. This implies that the appropriate empirical null hypothesis to test the prediction that $d_s < d_r$ is $u_s > u_r \mid t_s = t_r$.

III. Data and Empirical Strategy

Maize in Kenya is typically consumed as porridge prepared from maize meal. Packaged maize meal can be purchased packaged from shops, but in rural areas it is less expensive and much more common to take maize kernels – either grown on one's own farm or purchased on the informal market – to a local hammer mill for grinding. Sixty percent of the total maize meal processed in the country is ground in such mills, with the rest presumably milled in larger facilities (Kenya Maize Development Program, 2009, cited in Kirimi et al, 2011). To test the assumptions behind and predictions of the model, we use survey data and maize samples collected from over 1000 clients of such mills in Eastern Province, the part of the Kenya where aflatoxin contamination is most prevalent.

To select mills, the Eastern province was first stratified by agroecological zone. Districts, and then towns and mills were subsequently selected in each zone from a database of market centers using three-stage random sampling, with probability of selection approximately proportional to size. This resulted in a sample of 150 mills across 112 villages. Enumerators collected survey data and maize samples from a total of 1500 clients at these mills during July and August of 2010. A smaller scale survey of 100 clients at a randomly selected subset of five of the original mills, plus five mills in the western part of the country, was subsequently conducted in August 2012 to investigate hypotheses generated through analysis of the 2010 data.

During the main (2010) survey, visual maize quality was assessed for two thirds of survey respondents prior to any sorting of grain performed by the respondent at the mill. To do so, enumerators first mixed a customer's entire batch of unmilled maize kernels to achieve homogeneity, and then randomly selected a 100 gram sample for close inspection. An score reflecting the proportion of discolored kernels in this sample was recorded, as was a separate score indicating the proportion of broken kernels.

After milling, a separate 100 gram sample of maize flour was purchased from all consumers. The enumerator first mixed the entire batch of flour belonging to the consumer to achieve homogeneity, and then randomly selected the sample. Maize samples were sent to the Biosciences eastern and central Africa (BecA) laboratory in Nairobi for quantification of aflatoxin using enzyme-linked immunosorbent assay (ELISA) following manufacturer's instructions.[1]

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[1] Test kits were purchased from Helica Biosystems, Inc., Fullerton, CA. This test is sensitive up to 20 parts per billion. Samples were diluted and re-tested if the contamination level exceeded this upper limit. The distribution of estimated aflatoxin contamination, show in logs in Figure A1, is highly skewed to the right, with a distinct spike between 10 and 20 ppb. As this spike may be a function of the testing technology rather than the true distribution of aflatoxin, and since values over 20 ppb are measured with increasing error, we use a binary variable indicating whether aflatoxin is below or above 10 ppb in the analysis. This is the level of contamination considered safe for human consumption under Kenyan food safety regulations.

In these data, we are able to observe elements of both o (visible discoloration) from the visual maize inspection, and u (aflatoxin contamination). In the following section, we characterize the relationships between observable and unobservable attributes of maize, and between these attributes and prices. Although we do not directly measure the experience quality of maize, we do have data on the relatively difficult to observe attribute of kernel integrity. A kernel is considered broken if there is any damage to the hard outer pericarp, which may not be noticed by consumers at the time of purchase if the damage is minor, and is certainly less visible than discoloration. We can also infer the existence of a correlation between e and u quality based on the relationship between consumers' use of maize and aflatoxin contamination, which we do observe, but consumers do not. We then test for differences in the quality of home-produced and purchased maize.

Because we rely on cross-sectional data, our identification of a causal relationship between maize quality and use relies on the assumption this correlation is not driven by an unobserved variable which is associated both with both higher aflatoxin contamination in general, and a higher probability that maize is used for fermentation rather than consumed as food. Likewise, we must assume that unobserved characteristics are not driving some consumers to both consume contaminated maize generally (regardless of its source), and to purchase their maize on the market.

Since aflatoxin contamination, maize prices, and maize usage patterns may be both spatially and temporally correlated, we control for both village fixed effects and date of interview throughout the analysis relating these variables. When comparing purchased versus self-produced maize, however, the positive correlation between maize quality and quantity, together with the spatial correlation of these variables, implies that regions where maize quality is lowest are likely to import maize from regions with higher yields and lower aflatoxin contamination. Using fixed effects would thus result in a bias toward zero in the estimated difference in contamination levels between self-produced and purchased maize. We therefore estimate the effect of maize source using ordinary least squares, and standard errors clustered at the village level to account for the correlation of observations due to the sampling strategy. In all regressions, we present both a parsimonious specification, which includes only the independent variables suggested by the theoretical model plus a control for the date of interview, and one in which additional controls for the wealth and demographic characteristics of survey respondents are included.

In table one, we present summary statistics (columns 1 to 3), as well as provincially representative means from the 2008-9 Kenya Demographic and Health Survey (column 4). We then compare the characteristics of those who planned to consume maize as food versus those who planned to use it for some other purpose (column 5), and of those who had purchased the maize they were milling versus those who had brought maize from their own farms (column 6).

< TABLE 1 ABOUT HERE >

The majority of mill clients were female, with an average age of 37 years, and had completed primary school but not secondary school. Educational attainment in this sample is slightly lower than mean attainment, weighted by the gender composition of the sample, in Eastern province overall (column 3). Access to electricity, on the other hand, as well as asset ownership, is slightly higher in our sample. These differences may reflect the selection of the study sample from market towns, where access to infrastructure and participation in the cash economy are likely greater than the provincial average.

Column (5) shows the differences in means between those who planned to use maize for food, versus those who planned to use it for fermentation of alcoholic beverages, livestock feed, or sale.[2] In line with our empirical strategy for detecting the effect of maize characteristics on intended use, differences are estimated from a regression that includes village level fixed effects and clusters standard errors at the village level. Those who planned to consume their maize were more likely to be female, a difference significant at the 10 percent level. None of the other demographic or wealth variables differs significantly by planned use of maize. Data on farm practices are available only for the 62% of respondents who had brought their own maize to the mill. Within this group, there are no significant differences in the amount of land allocated to farming, yield per acre, or

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[2] Both here and in Section IV, we restrict our analysis of maize quality, use and pricing to the subsample for which visible quality data are available.

months since maize was harvested between those who planned to consume maize versus use it for some other purpose. To the extent that any unobservable characteristics that may be associated with both consumption and maize usage patterns are correlated with observable characteristics, the fact we find only one of 11 differences tested significant at the 10 percent level is reassuring.

Differences between those who were milling maize they had grown themselves, and those who had purchased their maize, are shown in column (6). Here, the sample is restricted to those who either purchased maize or grew it on their own farm themselves. Standard errors are clustered at the village level, but in keeping with the empirical strategy for testing whether purchased maize is more likely to be contaminated, fixed effects are not included. The only significant difference between respondents who were grinding their own grain versus those who were grinding purchased grain is in their ages: those who had purchased were two and a third years older on average.

While differences are not significant when village fixed effects are included, a strong correlation overall is evident between the use to which maize is put and the source from which it is obtained. As shown in column 6, purchased maize is 8.7 percentage points less likely to be used as food, and 10.4 percentage points more likely to be used for brewing.

Differences in both difficult to observe and unobservable qualities of maize destined for consumption versus other uses are also stark. Maize used for consumption is less likely to contain damaged kernels. It is also 8.3 percentage points less likely to be above the regulatory threshold of 10 ppb aflatoxin contamination. While the relationship between observable attributes and the source of maize is less striking, purchased maize is somewhat less likely to contain discolored kernels. Despite its slightly higher visible quality, however, purchased maize is 6.7 percentage points more likely to be contaminated with aflatoxin than maize grown by the respondent, a difference which is significant at the 5% level.

< TABLE 2 ABOUT HERE >

Table 2 presents information on consumers' behavior and perceptions related to maize quality. Almost all respondents to the main survey were either seen sorting maize prior to milling, or reported doing so at home, with 59% observed sorting at the mill. Three quarters of those who had sorted cited health reasons for doing so, with almost all of the rest saying they sorted maize to improve taste.

Among the 2012 sample, most respondents said they preferred home-grown maize to purchased. The most common response to an open-ended question about the reason for this preference was better drying or storage. Either storage or drying was mentioned by 67 percent of respondents who said they preferred their own maize. Factors related to cost were the next most common reason, given by 36 percent of respondents. Other quality considerations, including how well maize was sorted, its quality overall, and whether chemical pesticides had been applied were also important considerations, each cited by about a third of those who preferred to consume self-grown maize.

Perceptions about food safety are also telling. Only a fifth of respondents believed there was any chance that maize they themselves had grown could cause sickness, whereas 93% perceived a non-zero probability of becoming sick from maize purchased from a trader, and 30% assigned a probability of over 50% to such an event. Respondents generally used visible attributes to infer health quality, with only a third correctly reporting that maize of visually high quality could cause sickness. Relatively low awareness of aflatoxin corroborates the finding that most consumers believe only visual attributes matter to food safety: just over half of the sample reported that they had heard of aflatoxin before, and only 42% believed it was harmful to human health (these proportions are slightly higher for those surveyed in Eastern province, at 62% and 46% respectively). Only a third of consumers believed they could predict the taste of maize, either from their own farm prior to cooking it, or from a trader prior to purchase. However, most reported that after tasting maize from a particular bag, or a particular plot, they could infer how the rest of the maize from that source would taste.

IV. Results

We now turn to characterizing the relationship between observable maize quality attributes, aflatoxin contamination, and the use to which maize is put (Table 3, Panel A). Odd-numbered columns of Table 3 show results from basic regressions in which only the primary variables of interest are included, while even-numbered columns show specifications that include controls for demographics and wealth status. All specifications include a control for the interview date and village fixed effects. Standard errors are clustered at the village level. Because observable maize attributes are an important part of the analysis, we restrict the sample to those observations for which data on these attributes is available. Results in columns 1 and 2 show that the presence of broken kernels is highly correlated with aflatoxin contamination. Presence of broken kernels is likewise correlated with how consumers report maize will be used (columns 3 and 4). The fact that aflatoxin contamination further reduces the likelihood that maize is used for consumption while not affecting coefficients on the proportion of broken kernels (columns 5 and 6), suggests that consumers observe additional correlates of aflatoxin contamination not captured in the data. One possibility is that consumers have tasted a portion of the maize from which the portion they are milling was taken. It is also possible that other visible qualities, on which data was not collected, are used by consumers to make this decision. Finally, columns 7 and 8 show that the direct correlation between aflatoxin contamination and use of maize as food. This relationship is significant at the 10% level in the specification without controls, at the 5% level when these are included. Tests for the probability that the two observable quality coefficients are equal are shown below the regression results, and reveal that these are significantly different at the 5% level in two of the six specifications, and at the 10% level in three others.

< TABLE 3 ABOUT HERE >

The fact that contaminated maize is less likely to be used for food consumption reduces exposure to aflatoxin. Fermentation during brewing, the second most common use of maize in our sample, reduces aflatoxin content by between 73 and 82%. Taking the midpoint of this range, we estimate the level of contamination in beverages made by fermenting the maize in our sample. We then use the proportion of maize consumed as food and used in fermented beverages to estimate the average level of aflatoxin contamination in these two products. Compared to the counterfactual scenario that maize used for all purposes is equally contaminated, the fact that consumers are less likely to consume contaminated maize as food reduces the proportion of maize products consumed that exceed the 10 ppb threshold by 13%, and the average contamination level by 11%.

< TABLE 4 ABOUT HERE >

In contrast to the relationship between aflatoxin contamination and use of maize, contamination does not appear to reduce the price charged for maize (Table 5). Maize prices are available only for those cases in which maize was purchased, which limits the sample for these regressions to less than a third of those shown in Table 3. The failure to detect a significant relationship between price and aflatoxin could thus be due to a lack of power. A price penalty for the presence of visibly discolored kernels is, however, apparent. The fact that consumers paid significantly less for maize containing visibly discolored kernels, whereas broken grains exerted no discernible price penalty but a strong effect on consumption patterns suggests that either kernel integrity is difficult to observe prior to purchase, or that consumers do not equate damaged kernels with undesirable consumption attributes but that characteristics which are important to consumers, and correlated with kernel integrity (perhaps taste or illness after consumption), are observed after purchase.

< TABLE 5 ABOUT HERE >

Table 6 shows that both scale of maize production and yield are correlated with aflatoxin contamination, as is the time elapsed since harvest. Since more productive farmers supply a disproportionate share of maize available in the market, this implies that marketed maize should contain less aflatoxin, all else equal.

< TABLE 6 ABOUT HERE >

However, this is not what we find. Table 7 shows that maize obtained through purchase is more likely to be contaminated with aflatoxin than maize grown by the consumer. The difference is significant at the 5% level, both with and without controls for respondent characteristics.

< TABLE 7 ABOUT HERE >

If purchased maize has been stored for a longer period than maize grown by farmers, this could potentially explain our finding of higher aflatoxin contamination. However, if the difference in maize quality is driven only by time since harvest, we would expect other quality characteristics which deteriorate over time to also be lower in purchased maize. Columns 5 through 8 of Table 7 show that the characteristics of purchased and self-grown maize do not differ. If anything, the proportion of discolored kernels, which as shown in Table 5 has a negative impact on price, appears to be slightly lower in purchased maize, suggesting that visibly moldy grains may have been removed from maize. The proportion of broken kernels, which do not affect price, is almost exactly equal across purchased and self-grown maize. We note that the sample size is smaller for the visible attribute regressions, and that failure to detect significant differences could potentially be due to lack of power. Restricting the sample for the aflatoxin regression to the sample for which visible quality data are available, the coefficient on maize source is relatively stable, but standard error larger, rendering the difference between purchased and self-grown maize not significant at conventional levels. However, recalling that aflatoxin contamination should be lower in purchased maize, all else equal, a one-sided test of the difference is significant at the 10% level. The same test is nowhere near significant for any of the other maize quality characteristics.

According to Kirimi et al.'s (2011) analysis of Kenya's maize marketing system, most of this trade exploits spatial rather than intertemporal arbitrage opportunities. This is due to spatial variation in rainfall and harvest seasons across the country and region, as well as price risk due to unpredictable government import tariff and maize pricing policy. At all stages of the supply chain, Kirimi et al. find that traders generally rely on a strategy of minimizing storage time and transporting maize to regions with current maize deficits. Seasonal commodity flow maps compiled by the Famine Early Warning System Network (Awour, 2007) show that during July and August, the months of data collection for this study, maize is typically moving into eastern Kenya from the western part of the country, where aflatoxin contamination is much lower than in the study area. Given this structure of the maize market, it seems likely that the lower quality seen in purchased maize is driven by differences in how maize destined for sale and is handled, either by farmers or traders.

Table 8 shows additional summary statistics from the supplementary 2012 survey. Among the sample of 100 maize mill clients, only 38 grew maize. Of these, 32% (12 farmers) reported a difference in the quality of maize that they sold compared to that saved for home consumption. Most of the farmers who reported such a difference said that they sorted maize for home consumption more carefully, and half reported drying this maize more fully than the maize they sold. The meaning of 'better' chemical additives is ambiguous given the preference against such additives expressed by respondents as reported in Table 2. However, it is clear that the extent to which chemicals are used is another difference between retained and sold maize. Our interpretation of the data, based on enumerators' impressions of how the question was interpreted, is that farmers were more likely to apply chemical pesticides during storage to maize destined for sale than to maize which they planned to consume themselves. While the sample size for this survey is small, we take the results as suggestive evidence that a difference in post-harvest handling could underlie the lower perceived and objective quality of maize available on the market.

< TABLE 8 ABOUT HERE >

V. Conclusion

Consumers are responsive to maize characteristics that are correlated with aflatoxin contamination: maize containing aflatoxin is less likely to be consumed as food, and more likely to be used for other purposes such as the production of alcoholic beverages or livestock feed, or sold. This consumer response reduces exposure to aflatoxin by an estimated 11-13% relative to a counterfactual scenario in which there is no relationship between the quality of maize and the use to which it is put.

This may be through careful visual inspection of kernels: physical damage to maize kernels, which is correlated with aflatoxin contamination, reduces the likelihood that maize is consumed. However, we find no evidence of a direct link between aflatoxin contamination and maize prices. This suggests that prospective buyers have limited information prior to purchase about maize quality attributes they care about, and corroborates findings by an experimental study on the importance of unobservable quality to consumers' valuation of maize in this setting.

Higher aflatoxin contamination in purchased maize relative to that grown by consumers also points to information problems in this market. Finally, the results of a small scale survey of farmers reveals that a sizeable proportion handle maize destined for sale differently from that which their household will consume, suggesting a moral hazard problem. Data on maize quality from farmer's stores and that which is sold, collected on the same farm and at the time of sale to traders, as well as on marketed maize at different stages in the value chain, would allow for more conclusive analysis of the nature and consequences of the market imperfections suggested by the present study.

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Table 1: Respondent and maize characteristics

Source:	Survey data (main sample)			Kenya DHS (Eastern Province)	Plan to consume as food vs. not	Maize was purchased vs. home-grown
	Mean	Standard Deviation	N	Mean	Difference	Difference
	(1)	(2)	(3)	(4)	(5)	(6)
Demographics & Wealth Indicators						
Female	0.74	0.44	1494		0.065*	-0.037
Age	36.6	12.8	1500		0.559	-2.331**
Completed Primary Education	0.70	0.46	1496	0.81	-0.015	-0.003
Completed Secondary Education	0.17	0.37	1496	0.25	-0.016	-0.005
Household has electricity	0.13	0.34	1487	0.07	-0.017	-0.016
Household owns radio	0.88	0.33	1488	0.73	-0.017	-0.018
Household owns cell phone	0.80	0.40	1487	0.55	-0.041	-0.028
Household owns TV	0.24	0.43	1488	0.19	-0.009	-0.036
Agricultural practices						
Acres under maize cultivation	1.71	3.82	824		-0.461	
Yield per acre	647	879	809		-231.3	
Months since harvest	3.77	2.18	795		-0.049	
Maize origin and price						
Own farm	0.62	0.49	1369		0.044	
Purchase	0.32	0.47	1369		-0.046	
Gift	0.07	0.25	1369		0.002	
Price	14.00	4.01	415		0.304	
Intended use						
Food	0.61	0.49	1453			-0.087***
Brewing	0.33	0.47	1453			0.104***
Livestock	0.01	0.10	1453			0.001
Sell	0.05	0.21	1453			-0.018
Maize characteristics						
Broken kernels: 1-10%	0.28	0.45	1019		-0.117***	0.034
>10%	0.05	0.22	1019		-0.011	-0.020
Discoloration: 1-10%	0.32	0.47	1019		-0.052	-0.071*
>10%	0.08	0.27	1019		0.019	-0.007
Aflatoxin > 10 ppb	0.39	0.49	1500		-0.083**	0.067**

Table 2: Maize taste and safety perceptions and practices

	Proportion	N
Maize sorting behavior (main sample)		
Sorted maize prior to milling?	0.94	1486
Observed sorting at mill?	0.59	1486
Sorted for health	0.75	1354
Sorted for taste	0.24	1354
Preference for own maize (small sample)		
Prefer self-grown maize to purchased	0.89	94
Prefer purchased maize	0.04	94
Reason prefer own maize = drying or storage	0.67	84
= cost	0.36	84
= sorting	0.33	84
= quality	0.32	84
= no chemicals	0.29	84
Beliefs about maize safety (small sample)		
Likelihood maize grown on own farm causes sickness		
Impossible	0.80	100
0 - 50% chance	0.19	100
50% chance or greater	0.01	100
Likelihood maize purchased from trader causes sickness		
Impossible	0.07	100
0 - 50% chance	0.63	100
50% chance or greater	0.30	100
Maize may look fine, cause sickness	0.34	100
Knowledge of aflatoxin (small sample)		
Heard of aflatoxin	0.53	100
Believes aflatoxin harmful to health	0.42	100
Maize taste perceptions (small sample)		
Can predict taste of maize from…		
Trader prior to purchase	0.32	99
Own farm prior to cooking	0.34	100
Bag after cooking batch	0.74	90
Plot after cooking batch	0.68	90

Table 3: Observable characteristics, aflatoxin contamination, and use of maize

Dependent variable:	>10 PPB		Consume grain as food					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Broken kernel score (1-3)	0.128***	0.134***	-0.092***	-0.088***	-0.085***	-0.081**		
	(0.032)	(0.032)	(0.032)	(0.033)	(0.032)	(0.033)		
Discolored kernel score (1-3)	0.039	0.039	0.023	0.022	0.025	0.024		
	(0.032)	(0.032)	(0.032)	(0.033)	(0.032)	(0.033)		
Aflatoxin > 10 ppb					-0.047	-0.051*	-0.061*	-0.064**
					(0.030)	(0.030)	(0.031)	(0.031)
Additional client controls?	NO	YES	NO	YES	NO	YES	NO	YES
prob (β_{broken}=$\beta_{\text{discolored}}$)	0.109	0.085	0.038	0.054	0.047	0.068		
N	1000	1000	970	970	970	970	970	970
Clusters	107	107	107	107	107	107	107	107

Notes: Controls for date of interview and village fixed effects not shown. Columns (2), (4), (6) and (8) include controls for demongraphic and wealth indicators shown in Table 1. Standard errors clustered by village.

Table 4: Impact of consumer response to quality on aflatoxin exposure

	> 10 ppb	mean ppb	N
Aflatoxin contamination overall	0.37	41.1	970
estimated aflatoxin after fermentation	0.08	9.2	
Average predicted exposure with no sorting (food and beer)	0.29	31.9	
Aflatoxin contamination of maize consumed as food	0.31	35.8	655
Maize used for other purposes (overall)	0.50	52.2	315
brewing	0.47	45.5	266
estimated aflatoxin after fermentation	0.11	10.2	
livestock	0.50	64.7	12
sale	0.65	96.1	37
Average exposure after sorting (food and fermented)	0.25	28.4	
Reduction in exposure due to sorting	-13%	-11%	

Table 5: Determinants of maize price

	Price per KG (Kenyan Shillings)					
	(1)	(2)	(3)	(4)	(5)	(6)
Broken kernel score (1-3)	-0.146	0.002	-0.212	-0.089		
	(0.319)	(0.367)	(0.345)	(0.380)		
Discolored kernel score (1-3)	-0.910**	-1.102**	-0.931**	-1.166**		
	(0.387)	(0.469)	(0.394)	(0.486)		
Aflatoxin > 10 ppb			0.520	0.757	0.383	0.564
			(0.579)	(0.609)	(0.563)	(0.575)
Additional client controls?	NO	YES	NO	YES	NO	YES
prob ($\beta_{\text{broken}}=\beta_{\text{discolored}}$)	0.136	0.077	0.171	0.082		
N	306	306	306	306	306	306
Clusters	94	94	94	94	94	94

Notes: Controls for date of interview and village fixed effects not shown. Columns (2), (4), (6) and (8) include controls for demongraphic and wealth indicators shown in Table 1. Standard errors clustered by village.

Table 6: Determinants of aflatoxin contamination

	>10 ppb		Score for % broken kernels (1-3)		Score for % discolored (1-3)	
	(1)	(2)	(3)	(4)	(5)	(6)
Area	-0.011***	-0.009**	0.005	0.013	-0.013**	0.001
	(0.002)	(0.004)	(0.007)	(0.008)	(0.006)	(0.007)
Yield	-0.003**	-0.004***	-0.004**	-0.003	-0.002	0.000
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)
Months since harvest	0.024***	0.022**	0.030**	0.036**	0.029*	0.047***
	(0.009)	(0.009)	(0.015)	(0.016)	(0.017)	(0.016)
Fixed Effects?	NO	YES	NO	YES	NO	YES
Observations	882	882	570	570	573	573
Clusters	112	112	101	101	103	103

Notes: Columns (2), (4) and (6) include controls for demographic and wealth indicators shown in Table 1.

Table 7: Maize quality by source

	>10 PPB				Broken Kernel Score (1-3)		Discoloration Score (1-3)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Purchased	0.065**	0.059**	0.059	0.050	0.004	0.002	-0.066	-0.068
	(0.030)	(0.030)	(0.039)	(0.039)	(0.039)	(0.038)	(0.046)	(0.045)
Additional client controls?	NO	YES	NO	YES	NO	YES	NO	YES
Observations	1277	1277	875	875	879	879	875	875
Clusters	112	112	106	106	107	107	106	106
prob ($\beta_{purchased}$) < 0	0.014	0.025	0.066	0.100	0.463	0.476	0.843	0.861

Notes: All regressions include controls for date of interview. Additional controls in columns (2), (4) and (6) are demographic and wealth indicators shown in Table 1.

Table 8: Moral hazard and producer behavior

	Mean	N
Retained vs sold maize differ?	0.32	38
Better [practice or attribute] in retained maize		
Sorting	0.83	12
Drying and/or storage	0.50	12
Chemical additives	0.17	12
Kernel size	0.17	12
Better [practice or attribute] in sold maize		
Sorting	0.00	12
Drying and/or storage	0.00	12
Chemical additives	0.33	12
Kernel size	0.08	12

Notes: Data is from the supplementary survey conducted in August 2012.

Figure A1: Distribution of log ppb aflatoxin