INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

IFPRI

RESEARCH PROGRAM ON Agriculture for Nutrition and Health

CGIAR

Led by IFPRI

IFPRI Discussion Paper 01886

December 2019

Observability of Food Safety Losses in Maize: Evidence from Kenya

Vivian Hoffmann

Samuel K. Mutiga

Jagger Harvey

Rebecca J. Nelson

Michael G. Milgroom

Markets, Trade, and Institutions Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

The International Food Policy Research Institute (IFPRI), established in 1975, provides research-based policy solutions to sustainably reduce poverty and end hunger and malnutrition. IFPRI's strategic research aims to foster a climate-resilient and sustainable food supply; promote healthy diets and nutrition for all; build inclusive and efficient markets, trade systems, and food industries; transform agricultural and rural economies; and strengthen institutions and governance. Gender is integrated in all the Institute's work. Partnerships, communications, capacity strengthening, and data and knowledge management are essential components to translate IFPRI's research from action to impact. The Institute's regional and country programs play a critical role in responding to demand for food policy research and in delivering holistic support for country-led development. IFPRI collaborates with partners around the world.

AUTHORS

Vivian Hoffmann (v.hoffmann@cgiar.org) is a Research Fellow in the Markets, Trade, and Institutions Division of the International Food Policy Research Institute (IFPRI), Washington, DC.

Samuel K. Mutiga (mutiga@uark.edu) is a Postdoctoral Research Associate in the Dale Bumpers College of Agricultural, Food and Life Sciences, at the University of Arkansas.

Jagger Harvey (jjharvey@ksu.edu) is the Director of the Feed the Future Innovation Lab for the Reduction of Post-Harvest Loss at Kansas State University.

Rebecca J. Nelson (rjn7@cornell.edu) is a Professor in Plant Pathology and Plant-Microbe Biology Section at Cornell University.

Michael G. Milgroom (mgm5@cornell.edu) is a Professor in Plant Pathology and Plant-Microbe Biology Section at Cornell University.

Notices

Observability of Food Safety Losses in Maize: Evidence from Kenya

Vivian Hoffmann*
IFPRI
v.hoffmann@cgiar.org

Samuel K. Mutiga
University of Arkansas and
BecA-ILRI Hub
mutiga@uark.edu

Jagger Harvey
Kansas State University
jjharvey@ksu.edu

Rebecca J. Nelson
Cornell University
rjn7@cornell.edu

Michael G. Milgroom
Cornell University
mgm5@cornell.edu

Unlike physical losses, deterioration of food safety can be difficult to observe. In low- and middle- income countries, much of the food supply is never tested for safety hazards. We analyze data from 1500 maize samples and associated consumer surveys collected from clients of small-scale hammer mills in rural Kenya. We find that while visible damage to maize is penalized by lower prices, there is no correlation between price and aflatoxin, a carcinogenic fungal contaminant, implying an absence of market incentives to manage this aspect of food loss. Aflatoxin contamination is, however, correlated with consumer perceptions of quality, especially for self-produced maize, suggesting an information asymmetry that could lead to inefficiencies in this market.

JEL codes: O12, O13, O15

Acknowledgements: This research was supported through a grant from the Atkinson Center for a Sustainable Future at Cornell University and through the CGIAR Research Program on Agriculture for Nutrition and Health (A4NH). Sponsors of this research had no role in the study design; in the collection, analysis or interpretation of data; in the writing of the paper or the decision to submit the article for publication. We are indebted to Ken Gatobu for excellent survey management in Kenya, and to Sean Sylvia and Magda Tsaneva for outstanding research assistance. We thank Annemie Maertens, Erik Lichtenberg, Romina Ordoñez, Marc Nerlove, participants at the International Food Policy Research Institute and World Bank Poverty and Applied Micro Seminar for helpful comments on earlier drafts.

*Corresponding author: Vivian Hoffmann, International Food Policy Research Institute, v.hoffmann@cgiar.org.

Introduction

Losses of food are typically measured in terms of physical volume or economic value. Degradation of food safety is also an important aspect of food loss, but one which is often difficult to observe. While food safety hazards can be detected through specialized tests, low unit transaction values and the absence of traceability systems in most low- and middle-income countries imply that testing is often not economically feasible. The invisibility of food safety makes it difficult for value chain actors to address food safety losses and limits their economic incentive to do so. However, if food safety hazards are correlated with other, more observable attributes of food quality, markets may incidentally penalize these, and consumers may be able to divert contaminated foods to uses that reduce health risk.

Evidence on the existence and magnitude of price penalties for the correlates of food safety hazards can be used to inform the design policies to reduce foodborne illness. If hazards persist despite a strong price, this implies that other constraints are responsible for food safety failures; if a price signal is absent, this suggests that policies which make hazards easier to observe, such as the promotion of low-cost detection technologies, or certification of safer food, could potentially have a significant impact on adoption of practices to improve food safety. Further, if food safety is important but unobservable to consumers, this may lead people to control the quality of their food by producing it themselves, diverting resources from other, potentially more profitable activities.

Similarly, understanding how the use of agricultural products depends on their safety has implications for the importance of intervention from a public health perspective. If consumers are already mitigating their exposure by processing food in a way that reduces risk, the health implications may be less severe than the prevalence of a hazard would suggest.

In this paper, we describe the observable correlates of aflatoxin, a common food safety hazard in maize, and examine how these relate to consumer perceptions, prices, and the use to which maize is put. Aflatoxin is produced by a fungus endemic in soils. Dietary exposure to the toxin at high levels causes liver damage and death. Low-level, chronic exposure contributes significantly to the burden of liver cancer in developing countries (Liu and Wu, 2010) and is linked to impaired growth from gestation through early childhood (Gong et al., 2004; Turner et al., 2007; Hoffmann et al., 2018). Prevalence studies in Kenya's formal and informal maize sectors consistently show high average levels of aflatoxin contamination, with 16% to 83% of samples testing above the regulated maximum level (Lewis et al., 2005; Daniel et al., 2011; Okoth and Kola, 2012; Mutiga et al., 2014; Mutiga et al., 2015).

Crop stress during the growing season, particularly caused by drought conditions, can increase the risk of infection with the fungus that produces aflatoxin; post-harvest factors including contact with soil, insufficient drying, and exposure to moisture and insects during storage lead to fungal proliferation and associated production of the toxin during storage (Wilson and Payne, 1994; Hell et al., 2008). Food safety losses in grain are thus are caused by many of the same factors that lead to physical losses and degradation of its more readily observable qualities. As a result, aflatoxin contamination in maize is correlated with physically observable attributes (Matumba et al., 2015). In particular, physical damage to the protective outer layer of the maize kernel facilitates fungal infection, and fungal growth can sometimes (though not always) lead to discoloration of grain. However, physical grain damage also allows the growth of fungi that do not produce aflatoxin, and other fungi can cause discoloration, weakening the correlation between visible grain attributes and aflatoxin.

While previous work shows a negative relationship between price and aflatoxin contamination or branded, packaged maize flour in Kenya (Hoffmann and Moser, 2017), the extent to which observable correlates of aflatoxin contamination are penalized in unregulated grain markets has not previously been studied. A negative correlation between aflatoxin and price would imply the existence of an economic incentive to reduce aflatoxin, if only incidentally. Similarly, there is no existing literature comparing the level of contamination in crops consumed as food versus put to other uses, for example, for production of alcoholic beverages or as livestock feed. The way in which contaminated crops are used has an impact on human exposure to aflatoxin. Fermentation of grain to produce beer reduces the level of aflatoxin contamination by up to 82% (Chu et al., 1975). While some of the aflatoxin present in feed does pass through to the animal products consumed by humans (and exposure reduces animal productivity), levels of the toxin in these products are far lower than in the feed itself (Bhat et al., 2010).

We aim to fill these gaps by presenting evidence on how observable attributes of maize, its price, consumers' subjective perceptions of its quality, and the use of maize relate to aflatoxin contamination. This paper builds on a small body of literature relating observable qualities to the prices of agricultural commodities in informal markets (Langyinto et al., 2004; Kadjo, Ricker-Gilbert and Alexander, 2016). It relates to work on agricultural markets in India showing that absent external verification, information on attributes which are difficult to observe, for example pesticide use and source of irrigation water, does not circulate through the value chain and better quality on these dimensions is therefore not rewarded by higher prices (Fafchamps et al., 2008).

In the following section, we describe the study design, data, and analytical approach. Results are then presented as they relate to four questions: How do subjective perceptions of quality relate to food safety? Do informal markets reward food safety? How does food safety relate to how, and by whom, maize is used? Finally, we discuss the implications of our answers to these questions for both the efficiency of informal maize markets in developing countries, and public health.

2. Methodology

2.1 Sample selection and data collection

We use data from two surveys of hammer mill clients in rural Kenya. In Kenya, as throughout much of sub-Saharan Africa, consumers bring grain that they have either grown themselves or purchased in bulk as kernels on the informal market to small-scale hammer mills for grinding into flour. Hammer mills process an estimated 60% of the maize consumed in Kenya (Kang'ethe, 2011). Previous aflatoxin prevalence studies have used a hammer mill-based sampling approach to collect large, geographically representative samples of maize (Mutiga et al., 2014; Mutiga et al., 2015).

For the present study, we combine data on aflatoxin and observable maize quality as described in Mutiga et al. (2014) with previously unused variables in the same dataset on consumers' perceptions of maize quality, prices, intended use of maize, and socio-economic status. These data were collected in July and August of 2010. After selecting a study area based on agroecological characteristics, 10 districts and then 112 maize-growing villages within these districts were randomly selected. A total of 150 hammer mills were selected within the 112 villages, with the number of mills per village proportional to size of the village population. A figure showing the spatial distribution of study villages was previously published in Mutiga et al. (2014).

At each mill, ten clients were administered a brief survey and asked to provide a sample (in exchange for cash compensation) of the maize they had brought for grinding. Client's' unmilled maize was mixed to achieve homogeneity and a 100-gram sample was visually assessed and assigned a categorical score on two dimensions: percentage of broken kernels, and percentage of moldy, discolored, or rotten kernels. If time allowed, scoring was conducted twice: first before and then again after the client conducted any sorting of maize. However, since careful scoring is time-intensive, and enumerators were instructed to avoid taking too much of customers' time, maize was not scored at all in four cases, and was only scored once in 674 cases. In the analysis below, we utilize pre-sorting quality scores in the 1,299 cases for which these are available, as these reflect the quality of maize at the time of purchase, and since the same factors leading to visible damage in some kernels may also affect the aflatoxin contamination of those not visibly affected. The correlation coefficients between unsorted and sorted maize scores for the 822 observations containing both scores are 0.928 (discoloration) and 0.906 (kernel integrity). We therefore use post-sorting scores for the 197 cases in which unsorted scores are not available.[1]

Once the flour had been milled, enumerators mixed it to achieve homogeneity and procured a 35-gram sample. Samples were stored in Falcon™ tubes (Corning, NY) with silica desiccant packs, stored at ambient temperatures, and sent to a laboratory at the Biosciences eastern and central Africa (BecA) laboratory in Nairobi within 72 hours. Once at the laboratory, samples were stored at 4°C until they could be analyzed for aflatoxin using an enzyme-linked immunosorbent assay (ELISA) following manufacturer's instructions.[2]

[1] Our results are not sensitive to an alternative definition of the score variables, in which we use the post-sorting scores if available, and pre-sorting scores only when post-sorting scores are not available.

[2] 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.

In 2012, a second survey was administered to 10 clients each at a randomly selected subset of five hammer mills in the 2010 dataset. Data from this survey describe consumers' preferences regarding maize and their perceptions about its safety.

2.2 Data analysis

The relationship between aflatoxin contamination and price is potentially confounded by a number of factors. First, both aflatoxin contamination and maize prices tend to be highly spatially correlated. Second, maize prices in Kenya vary dramatically over time due to seasonal production patterns and limited storage capacity – for example, Stephens and Barrett (2011, Figure 1) report a 21.5% change in purchase price over a single month. Seasonality is also likely to affect both the visible quality and aflatoxin contamination of maize, due to quality deterioration during storage and changes over time in the region from which purchased maize is sourced (Kirimi et al., 2011). Third, consumer characteristics may be correlated with both quality and price. For example, cash-constrained consumers may purchase maize in small quantities, thus paying relatively high per-unit prices, and may also be more likely to consume lower-quality maize. Similar factors may confound the relationship between subjective maize quality and aflatoxin if contamination and the factors based on which subjective quality is assessed co-vary regionally, temporally or by socioeconomic or demographic characteristics. For these reasons, in the regression analysis presented below we control for interview date and village fixed effects, as well as variables indicating the gender, educational attainment, asset holdings, and age of survey respondents.

As our primary measure of aflatoxin contamination, we use a binary indicator of whether contamination exceeds the Kenyan regulatory threshold of 10 parts per billion (ppb). This threshold is approximately halfway between the lower and upper limits of detection for the assay used (1 and 20 ppb). Where space allows, we also include specifications using any detectable aflatoxin, and the logarithm of ppb aflatoxin, to test the robustness of our results.

3. Results

3.1 Sample characteristics

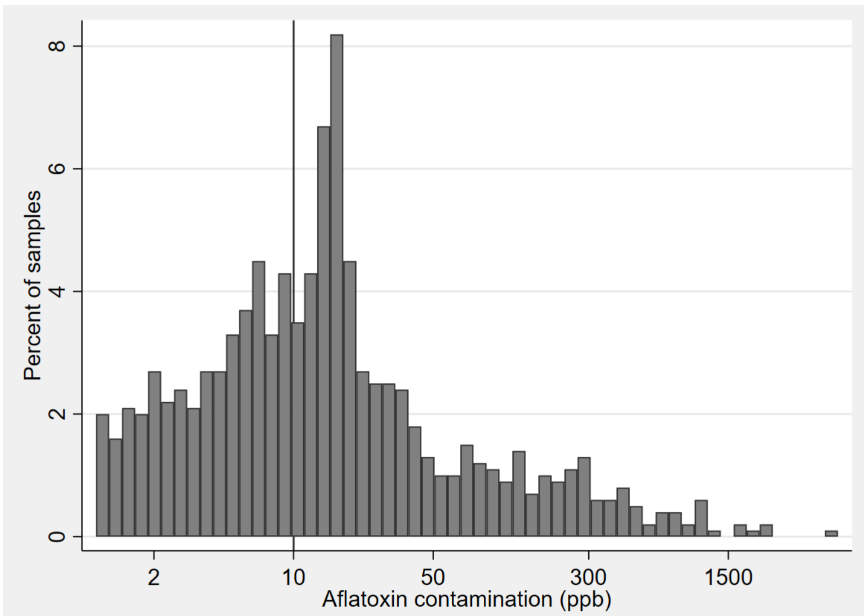
Table 1 presents characteristics of respondents to 2010 survey, and of the maize samples taken at this time. The majority (74%) of respondents were female, and the mean age was 37 years. Those who had completed primary school education accounted for 70% of the sample, and 13% of respondents had access to electricity in their home. The vast majority owned a radio (88%) and the rate of mobile phone ownership was slightly lower at 80%. Approximately a quarter of sampled households owned a television. Almost all respondents (95%) lived in a home with a metal or tile roof, and the proportions of those with walls made of brick or cement (as opposed to mud bricks), and cement or tile floors (as opposed to earth or plaster) were around half. For respondents who had brought self-grown maize for milling, the mean land area under maize (1.71 acres), yield per acre (647 kg), and months since harvest (3.77) are reported.

Of the 1500 hammer mill clients interviewed, 1369 (91%) knew the source of the maize they were milling. Of these, 62% had grown the maize on their own farm, 32% had purchased the maize, and 7% had obtained it as a gift. The primary intended use of maize (known by the respondent in 97% of cases) was for consumption as food (61%), while a third of respondents indicated that the maize would be used for fermentation to produce an alcoholic ‘local brew’, and relatively few (1% and 5%, respectively) reported that it would be used as livestock feed or sold.

	Mean	Standard Deviation	N
Demographics & Wealth Indicators			
Female	0.74	0.44	1494
Age	36.6	12.8	1500
Completed Primary Education	0.70	0.46	1496
Household has electricity	0.13	0.34	1487
Household owns radio	0.88	0.33	1488
Household owns mobile phone	0.80	0.40	1487
Household owns TV	0.24	0.43	1488
House walls are brick or cement	0.53	0.50	1412
House floor tile or cement	0.48	0.50	1431
House roof metal sheeting or tile	0.95	0.22	1475
Agricultural practices (for sub-sample milling own grain)			
Acres under maize cultivation	1.71	3.82	824
Yield per acre	647	879	809
Months since harvest	3.77	2.18	795
Maize origin and price			
Own farm	0.62	0.49	1369
Purchase	0.32	0.47	1369
Gift	0.07	0.25	1369
Price (Kenyan shillings)	14.00	4.01	415
Intended use			
Food	0.61	0.49	1453
Brewing	0.33	0.47	1453
Livestock	0.01	0.10	1453
Sell	0.05	0.21	1453
Maize characteristics			
Broken kernels: 1-10%	0.26	0.44	1496
>10%	0.04	0.20	1496
Discoloration: 1-10%	0.27	0.44	1496
>10%	0.07	0.25	1496
Aflatoxin detected	0.39	0.49	1500
Aflatoxin > 10 ppb	0.39	0.49	1500
Aflatoxin (ppb)	47.2	206.5	1500

Table 1. Respondent and maize characteristics, main sample

One third of scored samples included some broken kernels, and 40% contained kernels that were moldy, rotten, or discolored. The proportion of samples containing more than 10% of kernels in each of these categories was 5% and 8% respectively. Aflatoxin was detected in one third of samples. The mean level of aflatoxin was 47.2 ppb, and 39% of samples exceeded the Kenyan regulatory limit of 10 ppb. Figure 1 shows the distribution of aflatoxin on a natural logarithmic scale.



Notes: Horizontal axis is shown on a natural logarithmic scale; observations below the minimum detectable level of 1 ppb (33% of the sample) are excluded. The vertical line indicates the regulatory limit (10 ppb) for total aflatoxin in Kenya.

Figure 1. Histogram of aflatoxin contamination (ppb) in maize samples

3.2 Maize quality perceptions and practices

Table 2 presents descriptive statistics related to hammer mill clients' perceptions of maize quality and related practices. Almost all respondents to the 2010 survey either reported that they had removed damaged kernels or other impurities from their maize prior to bringing it to the mill or were observed to do so while at the mill. Three quarters of those who had sorted their maize said they did this for health reasons, while a quarter were motivated by taste quality.

Data from the 2012 survey echo Hoffmann and Gatobu's (2014) finding that consumers generally prefer maize they have grown themselves, with 90% of clients expressing this preference.[3] Of those who indicated that they preferred self-grown maize, two of the most common (nonexclusive) reasons given for this preference relate to aflatoxin risk: superior drying or storage practices (64%) and more careful sorting (30%). Other common reasons included cost (43%) and the absence of chemical additives (30%). Perceptions about food safety also reflect a perceived superiority of self-produced maize, with respondents far more likely to believe that consuming purchased maize, as opposed to home-grown maize, could cause illness. Just over 60% of respondents had heard of aflatoxin, and 30% correctly stated that maize which appeared to be high quality could nonetheless cause one to become ill.

	Proportion	N
Maize sorting behavior (main sample)		
Sorted maize prior to milling?	0.93	1486
Observed sorting at mill?	0.59	1486
Sorted for health	0.75	1354
Sorted for taste	0.23	1354
Preference for own maize (small sample)		
Prefer self-grown maize to purchased	0.90	49
Prefer purchased maize	0.04	49
Reason prefer own maize = drying or storage	0.64	44
= cost	0.43	44
= sorting	0.30	44
= no chemicals	0.30	44
Knowledge and beliefs about maize safety (small sample)		
Likelihood maize grown on own farm causes illness		
Impossible	0.82	50
0 - 50% chance	0.16	50
50% chance or greater	0.02	50
Likelihood maize purchased from market causes illness		50
Impossible	0.06	50
0 - 50% chance	0.46	50
50% chance or greater	0.48	50
Heard of aflatoxin	0.62	50
Maize may look fine, cause illness	0.30	50

Table 2. Maize taste and safety perceptions and practices

[3] One respondent claimed to never consume purchased maize and was thus unable to express a preference.

3.3 How do objective characteristics, subjective perceptions of maize quality relate to safety?

We begin our regression-based analysis by examining the relationship between the observable characteristics and subjective quality of maize and aflatoxin contamination in Table 3. As shown in column 1 of this table, samples with between 1 and 10% of broken kernels are 10 percentage points (pp) more likely to exceed the regulatory aflatoxin limit than samples without any such damage. In samples with over 10% of broken kernels, the probability of exceeding the standard is 25 pp higher than in samples with no broken kernels. The correlation between visible discoloration of kernels is weaker but marginally significant when at least 10% of the sample is discolored.[4]

In column 2, we restrict the sample to self-produced maize and examine the relationship between aflatoxin contamination and agronomic outcomes and storage duration. The directions of these correlations are as expected: lower yield, indicative of plant stress during growth of the maize crop, is correlated with higher aflatoxin, as is longer time since harvest. While this information is not typically available to buyers and thus not expected to affect price, producers could potentially make inferences about the quality of maize based on the health of their crop and the time elapsed since harvest.

Column 3 shows the relationship between subjective quality of maize and aflatoxin contamination. Grain rated by repsondents as being of lower than average quality is 23.5 pp more likely to exceed the 10 ppb threshold compared to maize described as average or above average quality. This relationship remains strong and signficant after controlling for the observable factors

---

[4] Using score variables based on the post-sorting scores if available, and pre-sorting scores only when post-sorting scores are not available, gives very similar results, but with a slightly worse model fit when relating scores to aflatoxin.

Dependent variable:	Aflatoxin > 10 ppb regulatory limit					
	(1)	(2)	(3)	(4)	(5)	(6)
Visible quality						
1-10% broken kernels	0.099***			0.329***	0.335***	0.297**
	(0.029)			(0.120)	(0.127)	(0.138)
>10% broken kernels	0.248***			0.643**	0.614**	0.688**
	(0.068)			(0.262)	(0.274)	(0.310)
1-10% discolored kernels	0.018			0.144	0.118	0.212
	(0.034)			(0.130)	(0.139)	(0.145)
>10% discolored kernels	0.106*			0.489	0.442	0.432
	(0.057)			(0.319)	(0.336)	(0.351)
Conditions of production						
Yield (100 kg / acre)		-0.004***				
		(0.001)				
Months since harvest		0.024**				
		(0.010)				
Subjective quality						
Worse than average			0.235***	0.211***	0.144**	
			(0.045)	(0.047)	(0.068)	
Worse than average X own farm					0.130*	
					(0.075)	
Source of maize						
Own farm					-0.044	-0.052*
					(0.029)	(0.031)
N	1475	882	1457	1451	1326	1255
Villages	112	112	112	112	112	112
R-squared	0.025	0.023	0.019	0.039	0.043	0.032

Notes: Coefficients from linear regressions with village fixed effects are shown, standard errors clustered at the village level are in parentheses. All specifications control for date of interview, respondent gender, age, primary school completion, and an asset index constructed as the first principal component of asset ownership and housing quality indicators shown in Table 1. Results shown in column (2) are based on observations of self-produced maize only, and the sample used in column (6) is restricted to maize that was either purchased or grown by the respondent (maize of unknown origin or received as a gift is excluded). Other columns are based on models that include all maize samples for which independent variables are defined; data on interview date, visual quality indicators, subjective quality rating, and source of maize reduce sample sizes. * p<0.10, ** p<0.05, *** p<0.01

Table 3: Correlates of aflatoxin in maize brought to hammer mills

of kernel integrity and discoloration (col 4). Reflecting the additional information available to those who produced grain, the relationship between subjective quality and alfatoxin contamination is stronger than for purchased grain (col 5). In line with the widespread perception among consumers that maize they have grown themselves is less likely to lead to illness than purchased maize, we find that controlling for visible quality, self-produced maize is slightly less likely to contain aflatoxin than purchased maize (col 6). We note that despite the statistically significant relationship between the physical attributes of maize, its production and storage history, and consumer perceptions of its quality, the percentage of variance in aflatoxin contamination explained by these variables is low, ranging from 2.3% to 4.3% across the models presented in Table 3.

3.4 Do informal markets reward food safety in maize?

Turning next to the correlates of price in Table 4, we see that maize containing between 1 and 10% discolored kernels faces a price penalty of approximately 7% of the mean price, and maize with a higher percentage of such kernels is discounted by 10%. The presence of broken kernels, however, does not significantly affect price (col 1). When controlling for visible attributes, neither subjective quality (col 2) nor aflatoxin contamination (col 3) are predictive of price. The estimated coefficient on aflatoxin remains statistically insignificant when these controls for visible quality are removed (col 4). Aflatoxin and price are similarly uncorrelated for alternative definitions of aflatoxin contamination (cols 5 and 6).

Dependent variable:	Price per KG					
	(1)	(2)	(3)	(4)	(5)	(6)
1-10% broken	0.017	-0.134	0.006			
	(0.327)	(0.317)	(0.336)			
>10% broken	-0.523	-0.624	-0.517			
	(0.709)	(0.734)	(0.706)			
1-10% discolored	-1.009**	-1.134**	-1.013**			
	(0.501)	(0.517)	(0.499)			
>10% discolored	-1.428*	-1.544**	-1.443**			
	(0.727)	(0.769)	(0.703)			
Low subj. quality		0.447				
		(1.035)				
Aflatoxin > 10 ppb			0.113	0.042		
			(0.436)	(0.423)		
Detectable aflatoxin					-0.472	
					(0.397)	
Log aflatoxin						0.086
						(0.159)
N	407	399	407	409	407	286
Villages	107	107	107	107	107	97
R-squared	0.119	0.120	0.120	0.096	0.124	0.137

Notes: Coefficients from linear regressions with village fixed effects are shown, standard errors clustered at the village level are in parentheses. All specifications control for date of interview, unit of purchase, respondent gender, age, primary school completion, and an asset index constructed as the first principal component of asset ownership and housing quality indicators shown in Table 1. * p<0.10, ** p<0.05, *** p<0.01

Table 4: Determinants of maize price in purchased maize

3.4 How does food safety relate to how maize is used, and by whom?

As we have seen that consumers are able to perceive differences in maize that correlate with aflatoxin contamination, we next ask whether aflatoxin contamination is related to how maize is used. Maize in Kenya is put to a variety of uses: it may be consumed as grain, fermented to produce an alcoholic beverage, or fed to livestock. Our sample contains very few observations of maize used for the latter two purposes. We therefore pool maize used for purposes other than household consumption in the analysis presented in Table 5. We find that hammer mill clients were less likely to say they planned to consume maize containing broken kernels (Table 5, col 1) – a correlate of aflatoxin contamination, as shown in Table 3. However, they were no more or less likely to consume maize judged as poor quality (Table 5, col 2). The correlation between aflatoxin contamination and broken grains illustrated in Table 3 is apparently too weak to result in any relationship between aflatoxin contamination and the use of maize (Table 5, col 3).[5] The lack of any statistical relationship between aflatoxin contamination and use of maize as food is consistent for other definitions of aflatoxin contamination (Table 5, col 4 - col 6). We note that much of the sorting of maize into different uses is likely to occur prior to milling; maize is seldom milled before being fed to animals, and the primary form in which this commodity is sold by farmers is as whole grain. The analysis presented here should thus be interpreted as pertaining primarily to the allocation of maize between fermentation and consumption as flour.

[5] Estimates presented in a previous version of this paper showed a relationship between aflatoxin contamination and use of maize. Those estimates were based on a larger dataset that included observations from a separate region of Kenya and used a random-effects model to capture variation across villages. While the co-variation across villages in aflatoxin and use of maize is also of interest, here we are interested in the question of whether within a given village with a given distribution of maize quality, the use of maize is related to its quality. We therefore control for village fixed effects, since unobserved village-level variation in aflatoxin could be correlated with both local uses of maize and source of maize through other channels such as soil fertility and level of economic development.

Dependent variable:	Maize used as food					
	(1)	(2)	(3)	(4)	(5)	(6)
1-10% broken kernels	-0.099***					
	(0.028)					
>10% broken kernels	-0.115**					
	(0.057)					
1-10% discolored kernels	0.017					
	(0.033)					
>10% discolored kernels	0.039					
	(0.050)					
Quality below average		-0.021				
		(0.039)				
Over 10 ppb			-0.027			
			(0.032)			
Detectable aflatoxin				-0.001		
				(0.027)		
Log aflatoxin					-0.002	
					(0.011)	
Aflatoxin (IHS)						-0.001
						(0.008)
N	1431	1415	1436	1436	1436	1436
Villages	112	112	112	112	112	112
R-squared	0.013	0.005	0.004	0.003	0.004	0.004

Notes: Coefficients from linear probability models; all specifications control for date of interview and include fixed effects capturing interview location, with standard errors clustered at the village level. Controls are included for respondent gender, age, primary school completion, and an asset index constructed as the first principal component of asset ownership and housing quality indicators shown in Table 1. * p<0.10, ** p<0.05, *** p<0.01

Table 5. Relationship between maize quality and use

Finally, we consider the relationship between aflatoxin contamination and socio-economic status. Table 6 shows the results of regressing various measure of aflatoxin contamination in maize destined for household consumption as grain on the socio-economic variables used as controls in the models presented above. We conduct this analysis separately for self-produced maize and purchased maize, since the relationship between maize quality and respondent or household characteristics is likely to be mediated by different mechanisms depending on its source.

Source of maize:	Self-produced	Purchased
Dependent variable:	Aflatoxin > 10 ppb	Aflatoxin > 10 ppb
	(1)	(4)
Respondent is female	0.047	-0.061
	(0.056)	(0.067)
Respondent age	-0.004*	0.001
	(0.002)	(0.003)
Completed primary education	-0.107**	0.078
	(0.048)	(0.073)
Household asset index	0.003	-0.037
	(0.014)	(0.027)
N	531	241
Clusters	104	85
R-squared	0.019	0.022

Notes: Coefficients from linear regressions with village fixed effects are shown, standard errors clustered at the village level are in parentheses. Sample restricted to maize consumed as food by the respondent's household. Both specifications control for date of interview, respondent gender, age, primary school completion, and an asset index constructed as the first principal component of asset ownership and housing quality indicators shown in Table 1. * p<0.10, ** p<0.05, *** p<0.01

Table 6: Relationship between respondent characteristics and contamination of consumed grain

We find that more educated, and possibly more experienced (as proxied by age), farmers tend to produce less contaminated maize (col 1). This could reflect the skill of such farmers in producing and preserving higher-quality grain, or the quality of their land. On the other hand, none of the socio-economic variables included in the model are significantly correlated with aflatoxin contamination in purchased maize (col 2). This is not surprising given the lack of a relationship between aflatoxin contamination and price in this market.

4. Implications for markets and population health

In this paper, we have described the extent to which contamination with aflatoxin, a widespread food safety hazard, is correlated with observable factors, and how contamination relates to maize prices and consumer behavior. We find that while observable correlates of aflatoxin exist, their power to predict contamination is low, and the price of bulk maize is uncorrelated with aflatoxin contamination in informal Kenyan grain markets. The health effects of consuming low-quality maize are of significant concern to study participants, 68% of whom sorted their maize for health reasons prior to grinding. But the weak correlation between visible attributes maize and aflatoxin means that consumers have little opportunity to avoid contaminated foods. Of the maize brought to hammer mills, contaminated samples were no less likely to be consumed as grain as they were to be fermented or put to other uses.

Consumers' subjective perceptions of grain quality are predictive of aflatoxin contamination, especially for maize produced on the consumers' own farms, for which information on growing and storage conditions is available. This suggests an information asymmetry that could underlie the widespread perception in Kenya, apparent in data presented here as well as in a previous study (Hoffmann and Gatobu, 2014), that home-produced maize is superior to that available for purchase. We find some evidence in support of this belief: sampled maize that was grown by consumers is slightly less likely to contain aflatoxin in excess of the Kenyan regulatory standard than purchased maize. Given potential differences in the geographical origin and timing of harvest of marketed versus home-produced maize, as well as the marginal statistical significance of this result, we hesitate to draw strong conclusions. However, recent work in Benin points to the potential for asymmetric information about food safety to adversely affect consumer health.

Ricker-Gilbert and coauthors (2019) find that producers concerned about food safety are more likely to apply storage insecticides to maize they sell compared to that which they consume.

While the lack of observability of food safety in informal maize markets implies a lack of incentives for farmers or intermediaries to address the widespread problem of aflatoxin contamination, this same lack of observability implies that contamination is relatively evenly distributed in the population across socio-economic strata. Previous work based on serum analysis has shown that aflatoxin exposure in eastern Kenya depends lower socio-economic status (Leroy et al., 2015). Our findings suggest that the higher aflatoxin exposure among lower-SES consumers is likely to be driven by the large share of these individuals' diet constituted by maize as shown by Muyanga et al. (2006), as opposed to particularly high levels of aflatoxin contamination in the maize they consume.

Technologies are being developed to increase the observability of aflatoxin contamination (Stasiewicz et al., 2017; Tao et al., 2019). These technologies have the potential to strengthen incentives for better grain handling and storage practices, but also to divide markets into safer and less safe segments, concentrating aflatoxin exposure and related adverse health effects among poorer consumers. To avoid this outcome, interventions to increase observability would need to be accompanied by promotion of aflatoxin-reducing technologies and regulatory action to remove highly contaminated grain from the food supply.

References

Bhat, R., Rai, R.V. and Karim, A.A., 2010. Mycotoxins in food and feed: present status and future concerns. *Comprehensive reviews in food science and food safety*, 9(1), pp.57-81.

Chu, F.S., Chang, C.C., Ashoor, S.H. and Prentice, N., 1975. Stability of aflatoxin B1 and ochratoxin A in brewing. *Applied Environmental Microbiology*, 29(3), pp.313-316.

Daniel, J.H., Lewis, L.W., Redwood, Y.A., Kieszak, S., Breiman, R.F., Flanders, W.D., Bell, C., Mwihia, J., Ogana, G., Likimani, S. and Straetemans, M., 2011. Comprehensive assessment of maize aflatoxin levels in Eastern Kenya, 2005–2007. *Environmental Health Perspectives*, *119*(12), pp.1794-1799.

Fafchamps, M., Hill, R.V. and Minten, B., 2008. Quality control in nonstaple food markets: evidence from India. Agricultural Economics, 38(3), pp.251-266.

Gong, Y., Hounsa, A., Egal, S., Turner, P.C., Sutcliffe, A.E., Hall, A.J., Cardwell, K. and Wild, C.P., 2004. Postweaning exposure to aflatoxin results in impaired child growth: a longitudinal study in Benin, West Africa. *Environmental health perspectives*, *112*(13), pp.1334-1338.

Hell K., P. Fandohan, R. Bandyopadhyay, K. Cardwell,et al. 2008. “Pre- and Post-harvest Management of Aflatoxin in Maize,” in *Mycotoxins: Detection Methods, Management, Public Health and Agricultural Trade,* Leslie et al. (eds). (Wallingford, UK: CABI Publishing).

Hoffmann, V. and Gatobu, K.M., 2014. Growing their own: Unobservable quality and the value of self-provisioning. *Journal of Development Economics*, *106*, pp.168-178.

Hoffmann, V., Jones, K. and Leroy, J.L., 2018. The impact of reducing dietary aflatoxin exposure on child linear growth: a cluster randomised controlled trial in Kenya. *BMJ global health*, *3*(6), p.e000983.

Kadjo, D., Ricker-Gilbert, J. and Alexander, C., 2016. Estimating price discounts for low-quality maize in sub-Saharan Africa: evidence from Benin. *World Development*, *77*, pp.115-128.

Kang'ethe, E. 2011. Situation analysis: Improving food safety in the maize value chain in Kenya. In: National Stakeholders Workshop on Aflatoxin Control Along the Maize Value Chain in Kenya. Food and Agriculture Organization (FAO), Nairobi, Kenya.

Kirimi, L., N. Sitko, T. S. Jayne, F. Karin, M. Muyanga, M. Sheahan, J. Flock, and G. Bor. 2011. A Farmgate-to-Consumer Value Chain Analysis of Kenya's Maize Marketing System. Working paper WPS 44/2011. Tegemeo Institute of Agricultural Policy and Development. Nairobi, Kenya.

Langyintuo, A.S., Ntoukam, G., Murdock, L., Lowenberg-DeBoer, J. and Miller, D.J., 2004. Consumer preferences for cowpea in Cameroon and Ghana. *Agricultural Economics*, *30*(3), pp.203-213.

Leroy, J.L., Wang, J.S. and Jones, K., 2015. Serum aflatoxin B1-lysine adduct level in adult women from eastern province in Kenya depends on household socio-economic status: A cross sectional study. *Social Science & Medicine*, 146, pp.104-110.

Lewis, L., Onsongo, M., Njapau, H., Schurz-Rogers, H., Luber, G., Kieszak, S., Nyamongo, J., Backer, L., Dahiye, A.M., Misore, A. and DeCock, K., 2005. Aflatoxin contamination of commercial maize products during an outbreak of acute aflatoxicosis in eastern and central Kenya. *Environmental health perspectives*, *113*(12), pp.1763-1767.

Liu, Y. and Wu, F., 2010. Global burden of aflatoxin-induced hepatocellular carcinoma: a risk assessment. *Environmental Health Perspectives*, 118(6), pp.818-824.

Matumba, L., Van Poucke, C., Njumbe Ediage, E., Jacobs, B. and De Saeger, S., 2015. Effectiveness of hand sorting, flotation/washing, dehulling and combinations thereof on the decontamination of mycotoxin-contaminated white maize. *Food Additives & Contaminants: Part A*, 32(6), pp.960-969.

Mutiga, S.K., Were, V., Hoffmann, V., Harvey, J.W., Milgroom, M.G. and Nelson, R.J., 2014. Extent and drivers of mycotoxin contamination: inferences from a survey of Kenyan maize mills. Phytopathology, 104(11), pp.1221-1231.

Mutiga, S.K., Hoffmann, V., Harvey, J.W., Milgroom, M.G. and Nelson, R.J., 2015. Assessment of aflatoxin and fumonisin contamination of maize in western Kenya. *Phytopathology*, *105*(9), pp.1250-1261.

Muyanga, M., TS Jayne, G., Argwings-Kodhek, G. and Ariga, J. Staple food consumption patterns in urban Kenya: trends and policy implications. Technical report, Tegemeo Institute of Agricultural Policy and Development, 2006.

Okoth, S.A. and Kola, M.A., 2012. Market samples as a source of chronic aflatoxin exposure in Kenya. *African Journal of Health Sciences*, *20*(1-2), pp.56-61.

Stasiewicz M.J. et al. 2017. Multi-spectral kernel sorting to reduce aflatoxins and fumonisins in Kenyan maize. Food Control 78: 203-214.

Stephens, E.C. and Barrett, C.B., 2011. Incomplete credit markets and commodity marketing behaviour. *Journal of Agricultural Economics*, 62(1), pp.1-24.

Tao F, Yao H, Hruska Z, Liu Y .2019. Use of Visible-Near-Infrared (Vis-NIR) Spectroscopy to Detect Aflatoxin B1 on Peanut Kernels. 73(4): 415-423.

Turner, P.C., Collinson, A.C., Cheung, Y.B., Gong, Y., Hall, A.J., Prentice, A.M. and Wild, C.P., 2007. Aflatoxin exposure in utero causes growth faltering in Gambian infants. *International journal of epidemiology*, *36*(5), pp.1119-1125.

Wilson D.M., and Payne G.A. 1994. "Factors affecting Aspergillus flavus Group Infection and Aflatoxin Contamination of Crops," in *The Toxicology of Aflatoxins: Human Health, Veterinary, and Agricultural Significance*, by Eaton DL, Groopman JD, eds., San Diego, CA: Academic Press. pp 309–315.

ALL IFPRI DISCUSSION PAPERS

All discussion papers are available **here**

They can be downloaded free of charge

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
www.ifpri.org

IFPRI HEADQUARTERS
1201 Eye Street, NW
Washington, DC 20005 USA
Tel.: +1-202-862-5600
Fax: +1-202-862-5606
Email: ifpri@cgiar.org