Firm heterogeneity in food safety provision: evidence from aflatoxin tests in Kenya

Christine Moser
Department of Economics
Western Michigan University
christine.moser@wmich.edu

Vivian Hoffmann
Department of Agricultural and Resource Economics
University of Maryland and IFPRI
V.Hoffmann@cgiar.org

Romina Ordonez
Department of Agricultural and Resource Economics
University of Maryland
rominao@umd.edu

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Abstract

How can food safety be provided in the absence of regulatory enforcement? What can explain heterogeneous responses to unenforced regulation across firms when certain food safety characteristics are unobservable to the consumer? Using data from over 900 maize flour samples representing 23 distinct brands in eastern and central Kenya, this paper explores the relationship between price, brand and aflatoxin contamination. Aflatoxin is a toxin common in maize, groundnuts and other crops around the world and, while it is unobservable to the consumer, it may be correlated with other quality characteristics. We find a strong negative correlation between price and contamination rates, which is consistent with certain brands investing more in quality to avoid loss of reputational capital.

1. Introduction

Ensuring food safety in developing countries with poor public-sector regulatory enforcement is a challenge. This is particularly true when producers have little incentive to voluntarily improve quality because the contaminant is unobservable to the consumer and the health concerns are primarily over chronic exposure that cannot be linked to their product. This is the case with aflatoxin—a by-product of fungal growth in a range of crops and a global problem. While routine testing and modern processing, handling and storage have largely eliminated the risk to consumers in the developed world, millions are exposed in developing countries (Strosnider et al. 2006). An additional risk factor for large parts of Africa is the important role of maize or groundnuts in the diet. In this paper, we use data on aflatoxin test results from processed maize flour in Kenya to demonstrate that, despite a lack of public-sector enforcement, higher-priced flours are more likely to meet the official regulatory standard.

Aflatoxin is a toxin produced by the *Aspergillus* species of fungus, and while consumption of high levels of aflatoxin can be fatal, of greater concern in the developing world is chronic exposure, which has been linked in numerous studies to liver cancer, suppressed immune response and child stunting. There are studies suggesting a synergistic relationship between aflatoxin and hepatitis that results in greater risk for liver cancer (Gnonlonfin 2013, Liu and Wu 2010). Multiple animal studies have demonstrated that aflatoxin exposure reduces feed conversion efficiency and causes growth retardation. Detectable levels of aflatoxin have been found in the cord blood of babies in a range of countries, including the United Arab Emirates (in 67% of samples), Kenya (37%) and Nigeria (22 to 82%). Children can be exposed in-utero, through breast milk and post-weaning. The levels detected in blood and urine are generally much higher in samples from developing countries (Khlangwiset et al. 2011).

Crop stress, such as drought or pest infestation, as well as inadequate drying or poor storage makes maize more vulnerable to *Aspergillus* fungal infection (Gnonlonfin 2013). Aflatoxins can be produced by the fungus both in the field and during storage. While visible mold may be an indication that contamination is present, high levels of aflatoxin can be present in foods with no noticeable impurity and contamination can increase during storage. It is found in a variety of crops and animal products, but the consumption of maize and groundnuts is the most common source of exposure worldwide (Khlangwiset et al. 2011).

Parts of Kenya have among the highest rates of aflatoxin exposure globally and have experienced some of the most severe recorded outbreaks (Daniel et al. 2011). The proportion of maize exceeding the allowable limit of aflatoxin in Kenya varies by region and year because of differences in climate and yearly rainfall patterns that may favor fungal growth. One study led by researchers from the US Center for Disease Control and Prevention tested maize grain samples in eastern Kenya over three years. In 2005 and 2006, two years considered outbreak years, 41 and 51 percent of maize grain samples tested above the regulatory limit respectively while in 2007 this fell to 16 percent (Daniel et al. 2011).

The legally allowable level of aflatoxin contamination in food for human consumption set by the Kenyan regulatory authority is no more than 10 parts per billion.[1] However, enforcement of this standard is weak, even in the formal market where the relatively small number of large millers makes testing and enforcement feasible.[2] Previous work has found evidence of poor testing protocols and corruption at some mills that allow poor quality maize to pass through the gates (Kirimi et al. 2011). The Kenya Bureau of Standards (KEBS) obtains samples both directly from mills and from store shelves for aflatoxin testing. While three millers interviewed reported being visited by KEBS for sampling, none had never been informed of a violation of the standard. In contrast, a previous independent study obtained and publicized by the Kenyan popular press (Githuru, 2011) found that 65% of samples from formal sector millers were contaminated, suggesting that enforcement of Kenya's de jure aflatoxin regulation is not achieving its objective in practice.

In this context, consumers have no way to ensure that they are purchasing uncontaminated maize, whether purchasing whole maize kernels in the informal market or packaged maize flour from large mills in supermarkets. At least one study suggests that Kenyan consumers recognize the problem of

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[1] There is no single international standard for allowable levels of aflatoxin. The standard in the US varies by use and by crop but for human consumption is generally 20 parts per billion (ppb). The EU standards also vary but are more stringent. For example, 2 ppb is the allowable level set for cereal crops meant for human consumption. Animals are also susceptible to aflatoxins but standards typically allow for higher levels of the contaminant in animal feeds (Dohlman 2003). The Kenya Bureau of Standards had initially set the allowable limit at 20 ppb, but in recognition of the high proportion of maize in the Kenyan diet, the standard was later changed to 10 ppb (Daniel et al. 2011).

[2] A 2009 report estimated that small-scale informal mills processed 60% of maize meal in Kenya, with the remainder presumably processed in larger, formal sector mills (Kenya Maize Development Program, 2009, cited in Kirimi et al, 2011).

unobservable quality in maize. In an experimental auction, Hoffmann and Gatobu (2014) find that consumers place a large premium on self-produced maize and provide evidence that this is due to unobservable quality (not specifically related to aflatoxin) in maize purchased in the market. When participants in the study were told that maize had been tested for aflatoxin, bids on market maize increased by approximately 7 percent.

This paper develops a simple model based on brand reputation to explain heterogeneous investment in food safety by producers when this attribute is unobservable to the consumer. We then provide evidence for the model using data from over 900 aflatoxin tests of maize flour samples in Kenya for 23 distinct brands and show a strong negative correlation between price and samples not meeting the regulatory standard. There are a few possible explanations for the observed negative relationship. First, millers with established brands fear an outbreak of illness linked to their product and are more careful to scrutinize the maize they purchase. Second, millers might expect strengthened government regulation or inspection in the near future. Third, aflatoxin contamination is correlated with other quality characteristics, such as moisture content at the time of purchase by the miller and refining during processing, and lower contamination is an unintended benefit.

The paper is organized as follows. The next section outlines a basic model of investment in improved food safety. Section 3 describes the study and data used in this paper and section 4 presents the results. The final section provides a discussion of the implications for food safety issues in developing countries.

2. Model of investment in unobservable quality

In developing a model of voluntary investment in unobservable food quality, there is a rich theoretical literature from which we can draw, including models of voluntary compliance with regulation and quality investments linked to brand reputation and differentiation. The frequently-cited model of d'Aspremot, Gabszewicz, and Thisse (1979) proposes "maximum differentiation" based on quality in a highly competitive market with a homogenous product. However, Bester (1998) shows that when consumers have imperfect information on quality, firms have lower incentives to differentiate their products.

Orosel and Zauner (2010) develop a model that has several features that are relevant to our case of millers in Kenya. First, they assume that the good's quality is unobservable to the customer before purchase. Second, there is a competitive fringe that will always produce low-cost product with zero investment in quality. Based on discussions with shop owners and millers in Kenya, there are many small, regional mills that are producing the cheapest flour for the market. However, the objective of the Orosel and Zauner model is to show how brands and pricing strategies emerge and quality is revealed to consumers after purchase, while in our case, quality is not revealed to consumers (unless an outbreak occurs) and we are interested in how established brands might react to emerging food safety threats.

Among the models examining voluntary versus mandatory standards, that of Segerson (1999) suggests that when consumers are able to observe safety attributes, voluntary provision of food safety is more likely than when food safety is unobservable. However for both the observable and unobservable cases, the threat of mandatory standards can induce voluntary compliance. Fares and Rouviere (2010) build on the Segerson model by comparing the effects on firm behavior of (1) the threat of mandatory enforcement, and (2) low versus high risk of contamination. In their model, the firms can earn additional net benefits from increasing consumer demand as a result of improved food safety. In both the Segerson (1999) and Fares and Rouviere (2010) models, firms are homogenous and make a binary choice to either comply or not comply with a standard, rather than a choosing the level of investment in food safety.

In our model, we begin with firms that are already established and assume that the market is in equilibrium with a continuum of producers from low-priced with no brand-capital to high-priced with high brand capital. The firm's price and marginal cost are functions of established brand capital, B_i. Following Orosel and Zauner (2010), we assume that there is a competitive fringe of "no-names" who lack brand capital and must sell at the market equilibrium price, $p(B_0)$. Firms with brand capital earn positive rents such that $p(B_i) - c_B(B_i) > p(B_0) - c_B(B_0) = 0$. We abstract from quantities and assume constant marginal costs with respect to quantity.

Now suppose that firms and consumers become aware of a food safety issue, but consumers cannot observe contamination (such as with aflatoxin or pesticide residues). In the absence of regulatory enforcement, the incentive for firms to invest in food safety arises from the potential cost to the firm in the case of an outbreak resulting in illness or death linked to their product, or from information becoming public that their product is contaminated.[3] This cost could be legal liability for harm or from loss of brand capital; we focus on the latter. Let *r* be the probability of an outbreak or information about a bad test result that would cost the firm its expected profits and let *r* be a function of investment in food safety, s. The cost of investment per unit of sale in food safety, c_S, is assumed to be linear and an increasing function of s. Let $r'(s)<0$, and $r''(s)<0$.

The firm's expected profit per unit of sale can be described by

$$(1 - r(s))(p(B_i) - c_B(B_i)) - c_S \cdot s \tag{1}$$

The profit-maximizing firm chooses the level of investment in food safety such that the marginal cost of food safety investments equals the expected gain from continued existence of brand capital, $c_s = -r'(s) \cdot [(p(B_i) - c_B(B_i)]$. Thus both greater brand capital and higher perceived returns to food safety investments (for example when the probability of food safety problems in the absence of preventive

[3] The study publicized by Gathura writing for the Daily Nation, did not name specific millers, but its report that 65% of maize flour was contaminated caused a stir among maize millers, and prompted several of them to invest in improved aflatoxin safety equipment.

action is believed to be high) will lead to higher investment in food safety. Because firms with the least brand capital invest the least in food safety (and, in fact, those with zero brand capital invest nothing), there may be distributional implications for voluntary enforcement if poor consumers cannot afford to buy the higher quality brands. Furthermore, if the probability of contamination is negatively correlated with other investments in quality, firms already selling high-quality products may not need to invest as much specifically in food safety to reduce risk as those selling low quality product. This is relevant for the case of aflatoxin because several quality characteristics, such as low moisture and higher levels of refining are associated with lower levels of contamination (Bennet and Anderson 1978).

In the case of aflatoxin, the regulatory standard is set to minimize the effects of chronic exposure—a level much lower than what would be necessary to cause immediate sickness or death. In the absence of reliable and systematic testing, chronic exposure would continue to go undetected. Therefore, if firms perceive the risk of an outbreak of acute aflatoxicosis or of information about the true aflatoxin level of their product to be very small, then firms may continue to provide a product that exposes the public to the chronic risks absent the threat of regulatory enforcement. On the other hand, as our discussions with millers suggests, fear of publication of test results may be sufficient to spur investment in food safety for some firms.

Another consideration particularly relevant to the Kenyan case is that suppliers outside the formal sector may be difficult or even impossible to regulate. This implies that an increased threat of enforcement increases food safety in the formal sector by increasing the amount of poor quality maize rejected by the mills, which could then potentially enter the informal market. While our study is limited to packaged maize flour in the formal sector, potential implications for the large informal sector need to be kept in mind.

3. Data

This paper uses a record of over 900 aflatoxin test results, brand, price and package size (1 or 2 kilograms) observations to study the correlation between price and contamination rates. These data were collected as part of a pilot study in 2013 conducted to gauge consumers' willingness-to-pay for aflatoxin-tested maize. This study was conducted over several months in eleven shops and small supermarkets in eight different towns in eastern and central Kenya. These areas were chosen because of the relatively high level of aflatoxin awareness compared to other areas of Kenya.

The study was structured as follows. The team tested packages of maize flour stocked on the shelves of stores using rapid binary tests that indicated whether the aflatoxin level in a given sample exceeded the official Kenyan regulatory limit of 10 ppb. The sample of brands was selected to represent the sales volume of each brand at each store, according to the store manager. Maize testing negative was labeled as having been tested for aflatoxin and put back on the shelves; maize testing positive was disposed of. Tested maize flour was then offered to shop customers at prices ranging from 0 to 20 percent above the untested flour of the same brand and consumers were asked to participate in a short exit survey. Because the study design required meeting expected demand for aflatoxin-tested maize of each brand at a particular store, the number of tests conducted per brand varies widely.

We have 23 different brands in our data set. Prices ranged from 43 to 86 Kenyan shillings per kilogram. Some of the price difference is explained by how refined the flour is, but certain brands known for consistent quality or taste are also more expensive and there are many small, regional millers competing purely on price.

Our tests found that 26 percent of maize flour did not meet the national standard for aflatoxin contamination. Among the brands for which there are more than 6 observations, contamination rates range from 5 to 83 percent; table 1 summarizes these data. Figure 1 shows the percent of samples not meeting the regulatory standard by brand and price per kilogram for both one and two kilogram packages. This figure provides the first indication of a correlation between aflatoxin test results and price.

In addition to the correlation between the test results and prices, we can also look at whether test results correlate with consumers' views of different brands. As part of the consumer willingness-to-pay survey, we asked consumers why they purchased a particular brand and consumers were allowed to list multiple characteristics.   For each major brand, we can calculate the proportion of consumers of that brand citing a particular characteristic and then correlate that with the contamination rates for that brand. We have 431 consumer responses across 9 brands with at least 15 consumer responses per brand. The Spearman correlation coefficients and significance levels are summarized in table 2. Pairwise correlation coefficients produce similar results. Brands more likely to be valued for being "clean" have lower rates of contamination. Clean in this case is a broad term meaning free from dirt or mold and not specifically related to aflatoxin. Brands consumers choose for their low price tend to have higher rates of contamination—a result consistent with those elsewhere in the paper.   How the flour cooks and color could conceivably be related to contamination rates because these in turn are often correlated with how refined the flour is (refining removes the hull and sometimes the germ, which can reduce the amount of aflatoxin in the final product). However, these are not correlated with contamination rates in these data, possibly because some consumers prefer less refined flour or different cooking qualities and our question did not specify the direction of the preference.

4. Empirical results

The previous section provided some evidence that higher priced flours have lower contamination rates and this section explores this relationship further with additional analysis. While our data set includes over 900 observations, this is somewhat misleading because we have only 23 distinct brands and for some brands we only have a few observations. Prices per kilogram do vary within brands because of different locations, package size and purchase dates, but there is obviously a strong brand effect on price. We present two estimation approaches: the first aggregates the data to the brand level and uses the percent of samples testing positive by brand as the dependent variable, and the second uses the full set of test results.

Table 3 presents results for a regression of the percent of positive test results by brand on the average price for that brand. Because there is a trade-off in this data set between having a large enough sample of tests for a particular brand to be considered reliable and having enough brand observations to run a regression, we estimate separate models for brands with at least 5, 10, and 15 test observations per brand in models I, II and III respectively. Model I finds that price is negatively related to the percent of samples testing positive and this is significant at the 5 percent level. The coefficients in models II and III remain negative, but only statistically significant at the 20% level given the small number of observations.

The next set of estimations uses a linear probability model with the full (pooled) data set of 919 observations. The dependent variable is binary (1=a positive test) and the standard errors are clustered by brand. The large number of observations allows us to add additional control variables. Model I in table 4 uses price as the only explanatory variable and it has a strongly significant, negative effect on the probability of testing positive for aflatoxin contamination. Every 10 Kenyan shilling increase in price reduces the probability of testing positive by 10 percent. Taking the highest priced brand (A) and the lowest priced brands (O and S) from table 1, the model predicts that flour of the highest priced brand is 25 percent less likely to test positive.

Model II adds a dummy variable that equals one if the package size is two kilograms (as opposed to 1 kilogram packages). Interestingly, two kilogram packages are less likely to be contaminated. There are a few possible explanations. First, since we are not controlling for brand, low quality brands might be more likely to sell one kilogram packages marketed to poor consumers who can only buy small quantities at a time. Second, there could be a difference between the two package sizes in how quickly they are sold or how frequently they are milled as longer storage time is associated with greater risk of contamination. The price coefficient in model II is the same as in model I, suggesting that the second explanation is more likely.

Model III in table 4 adds vendor dummies. Because the testing took place over several months beginning with vendor 1 and ending with vendor 11, these dummies control for both location and time period. Again, price is negatively related to the test result. The coefficient increases slightly in absolute terms from -0.010 to -0.012. The final model (IV) drops the two highly refined brands of flour with the highest prices—brands A and E in table 1—to ensure that results are not driven by these outliers. The coefficient and statistical significance fall slightly, but the negative relationship between price and contamination remains.

The evidence presented in this section and the previous section are consistent with our model of brand capital in that higher priced brands do seem to provide safer maize flour to the market even though this characteristic is unobservable to the consumer and the official regulation is not well enforced. Some of this effect may be driven by correlation between contamination and other quality characteristics such as refining and moisture content. While we are unable to control for these characteristics directly, the price-contamination relationship holds when drop the most highly refined brands.

5. Discussion

Improving food quality in the context of poor regulatory capacity is a challenge in many parts of the world. This is particularly true when the contaminant is unobservable to the consumer. We study this issue in the context of aflatoxin contamination in maize flour in Kenya and find that price is strongly correlated with a lower likelihood of contamination. The magnitude of the effect is quite large—our model predicts that the lowest priced brands in our sample are 25 percentage points less likely to meet the regulatory standard for aflatoxin than the highest priced brands. There are a few possible explanations for this relationship and we develop a model to explain heterogeneous investment in food safety. First, millers with higher-priced, established brands may have more to lose if an outbreak is linked to their product or if the results of aflatoxin tests performed on their product become public. Second, millers might expect that the government may begin enforcing regulations in the future and some firms may be better able to invest in testing capacity in anticipation of this. Finally, aflatoxin contamination may be correlated with other quality characteristics, such as moisture content and refining, and lower contamination is an unintended benefit.

Our results and discussions with millers suggest that certain millers are taking steps to provide safer maize to the market. However, in the absence of regulatory enforcement, it is likely that a segment of the market will continue to sell on price and fail to invest in safety. This implies that purely voluntary enforcement has important distributional implications because poorer consumers who cannot afford higher-priced flours will be at risk of greater exposure to aflatoxin.

While our study focuses on the formal sector market for milled and packaged flour, these distributional concerns extend to the larger informal market where consumers purchase whole maize grains in bulk. While there has been no systematic comparison of contamination rates between the informal and formal sector maize in Kenya, anecdotal evidence and the fact that some standards for moisture content and aflatoxin are (imperfectly) applied in the formal sector suggest that contamination rates are likely higher in the informal sector. An additional concern is that if millers comply with aflatoxin standards in the formal sector, there is a risk that contaminated maize will be pushed to the informal sector and poorer consumers. Because of the number of points of sale and the difficulty in tracing bulk sales, regulatory enforcement will be difficult in the informal sector.

There are scenarios under which improved food safety in one segment of the market could instead have a pulling-up effect on the rest of the market. First, improved quality in one segment of the market might lead to increased consumer awareness of aflatoxin and greater demand for quality. Second, millers and traders might begin to demand (and pay for) better quality from farmers. However, because our work provides evidence that heterogeneous investment in quality is already occurring, all segments of the market need to be monitored going forward to limit the potential for the poor being at greater risk of exposure to aflatoxin.

In terms of the broader implications of our results, this study demonstrates both the potential and the risk of relying on private sector voluntary compliance with food safety regulation. Our case of unobservable quality and risks of chronic exposure is relevant to many contaminants, such as pesticides and heavy metals. While some firms may have incentives to invest in safety, relying on purely voluntary compliance may put some consumers at greater risk if the market is segmented.

Table 1. Test results by average price and brand

Brand	Percent of samples testing positive (>10ppb)	Price per kg Ksh	Standard dev. of price	Number of packages sampled
A	5%	70.45	(4.23)	121
B	15%	55.69	(3.35)	65
C	17%	61.00	(0.00)	6
D	17%	53.54	(4.36)	24
E	17%	71.66	(3.03)	29
F	22%	52.30	(3.84)	23
G	24%	49.33	(2.65)	38
H	24%	57.91	(5.31)	80
I	26%	56.51	(4.38)	198
J	27%	45.86	(2.27)	11
K	28%	50.65	(1.86)	94
L	29%	52.52	(5.25)	49
M	40%	58.00	(4.14)	15
N	44%	52.62	(3.24)	61
O	44%	45.00	(0.00)	9
P	45%	53.92	(3.55)	44
Q	50%	57.50	(5.67)	36
S	83%	45.00	(0.00)	6
Total*	26%	56.99	(7.82)	919

*total includes brands with <6 obs. not shown in table.

Table 2. Correlation between brand characteristics (as indicated by consumers) and rates of contamination

Spearman correlation	**Clean**	**Low price**	**Taste**	**Cooking**	**Color**
Correlation coefficient	-0.834	0.580	0.317	0.057	-0.025
Significance level	(0.005)	(0.102)	(0.407)	(0.884)	(0.949)
N	9	9	9	9	9

Table 3. Regression of rate of positive tests on price by brand

	Model I Brands with 5 or more test results		**Model II Brands with 10 or more test results**	**Model III Brands with 15 or more test results**
Mean price	-1.33	**	-0.66	-0.79
	(0.508)		(0.462)	(0.515)
Constant	104.12		64.48	72.21
	(28.140)		(26.011)	(29.362)
Observations	18		15	14
R-squared	0.30		0.14	0.16
Adj R-squared	0.26		0.07	0.09

Note: *** p<0.01, ** p<0.05, * p<0.1

Table 4. Linear Probability Model using individual test results

Dependent variable =1 if test result is positive	Model I Price only		Model II With pkg size		Model III With vendor dummies		Model IV Dropping highly refined brands	
Price	-0.010	***	-0.010	***	-0.012	***	-0.009	*
	(0.003)		(0.002)		(0.002)		(0.005)	
2 kg package			-0.107	***	-0.062	**	-0.038	
			(0.029)		(0.025)		(0.026)	
Vendor dummies								
Vendor 2					-0.027		-0.025	
					(0.133)		(0.135)	
Vendor 3					0.002		0.025	
					(0.120)		(0.119)	
Vendor 4					-0.024		-0.087	
					(0.117)		(0.125)	
Vendor 5					-0.130		-0.152	
					(0.126)		(0.133)	
Vendor 6					0.047		0.033	
					(0.131)		(0.140)	
Vendor 7					-0.025		-0.083	
					(0.112)		(0.112)	
Vendor 8					-0.059		-0.079	
					(0.115)		(0.113)	
Vendor 9					-0.148		-0.166	
					(0.107)		(0.108)	
Vendor 10					-0.174		-0.201	*
					(0.106)		(0.106)	
Vendor 11					-0.053		-0.056	
					(0.113)		(0.115)	
Constant	0.843		0.910		1.077		0.927	
	(0.159)		(0.126)		(0.137)		(0.274)	
Observations	919		919		919		769	
F	13.68		17.35		28.35		17.63	
Prob > F	0.0013		0		0		0	
R-squared	0.0339		0.047		0.072		0.040	
Root MSE	0.42986		0.427		0.424		0.450	

Note: *** p<0.01, ** p<0.05, * p<0.1

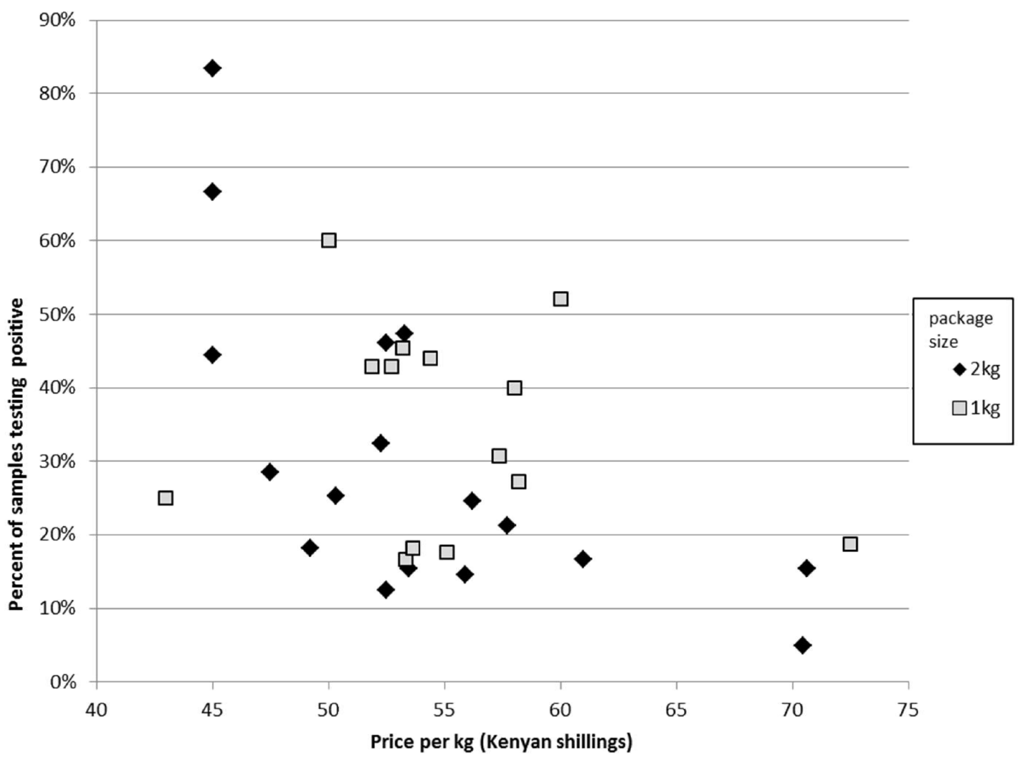

Figure 1. Percent of samples testing above the 10ppb limit by price (for brands with 6 or more samples shown)

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