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Introducing an aflatoxin-safe labeling program in complex food supply chains: Evidence from a choice experiment in Nigeria

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ABSTRACT

Food contaminated with aflatoxins is one of the more prominent food safety issues facing developing countries. These toxins impose an immense burden on countries that have to deal with the repercussions of the contamination. Repercussions include increased public health concerns, increased health care expenditures, and other economic tolls. To alleviate these food safety concerns, the implementation of aflatoxin-safe certification can potentially incentivize and elevate food safety standards. This study uses a discrete choice experiment approach to assess if traders are willing to pay a price premium for aflatoxin-safe maize and whether such a premium varies across their market channels. Results indicate that maize traders who sell to other traders, large feed mills, food companies, and retailers exhibit a higher willingness to pay (WTP) for aflatoxin-safe certification compared to those who sell to small feed mills and consumers. Relevant policy implications are discussed.

1. Introduction

The public health and economic impacts of poor enforcement of food safety regulations are often overlooked in developing countries (Hoffmann and Jones, 2018). These impacts are exacerbated when important attributes of food products are unobservable (Hoffmann and Gatobu, 2014; Kadjo et al., 2016). This is the case with certain highly toxic poisons produced by Aspergillus flavus and Aspergillus parasiticus fungi called aflatoxins. While not visible to the naked eye, the consumption of aflatoxin-contaminated food has been linked to a host of human and animal health concerns. For humans, aflatoxins cause liver cancer (hepatocellular carcinoma, HCC) and have been linked to acute liver toxicity and immunotoxicity (Wu et al., 2014). In chickens, the consumption of aflatoxin-contaminated feed affects growth, results in brittle eggshells, and also decreases egg production (Bandyopadhyay, 2013).

For observable food quality attributes, it is usually relatively easy to impose penalties for the sales of low-quality products. For example, Kadjo et al. (2016) found that buyers in Benin discount maize prices for grains that are damaged by insects. In contrast, when sellers have more information than buyers about potential food safety risks, they are less likely to consume that item themselves and more likely to sell it (Kadjo et al., 2019). Although some key players along the food value chain (e.g. food processing companies) are careful to provide food items that comply with safety regulations for fear of losing their customer base (Hoffmann and Moser, 2017), the economic incentive for them to do so is limited. Hoffmann et al. (2020) show that the price markup associated with aflatoxin-safe maize promoted via a marketing campaign by a major provider of maize flour on the Kenyan market does not persist when the campaign ends. When important attributes of food products are unobservable, disregarding food safety regulations can have devastating impacts because consumers are unlikely to realize they have purchased a highly toxic product.

While many developing countries have established standards on the acceptable levels of aflatoxin in maize, there is limited enforcement of these standards. There are often no market mechanisms to encourage the enforcement of the standards for consumers (Adetunji et al., 2014; Bakoye et al., 2017; SON, 2008).[1] Furthermore, there is often limited knowledge among direct maize consumers about aflatoxins and the dangers of consuming aflatoxin-contaminated maize products (Caputo

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[1] A market-based approach does not preclude the need for improved enforcement of existing regulations on acceptable aflatoxin levels in food products to minimize/remove dangerous products from markets.

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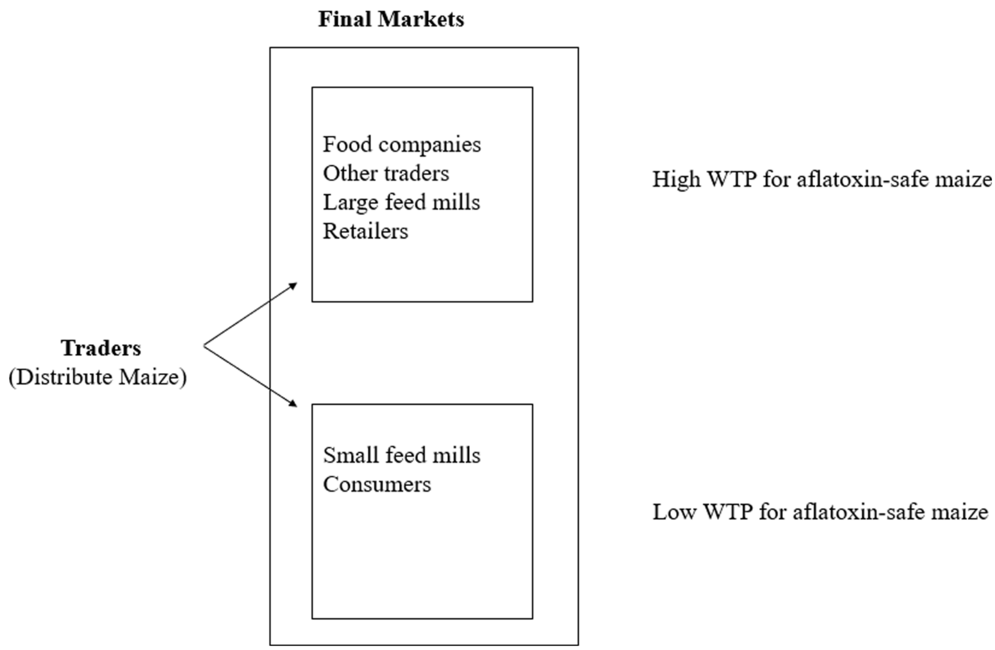

Fig. 1. Marketing channels of maize traders and hypotheses on WTP for aflatoxin-safe maize.

and Liverpool-Tasie, 2018; Hoffmann and Gatobu, 2014; Hoffmann and Jones, 2017; Hoffmann and Jones, 2018; Hoffmann and Moser, 2017). Limited awareness results in the absence of a recognized premium tied to the supply of aflatoxin-safe maize products. However, certain consumers of maize have a clear preference for high quality maize. For example, industrial food processors and major livestock feed producers are very particular about the quality of what they produce and hence their inputs (Hoffmann and Moser, 2017). Reasons for their heightened preferences include export considerations, traceability, and brand reputation (Hoffmann and Moser, 2017).

This study capitalizes on maize buyers' heterogeneous preferences for maize attributes related to food safety to explore the potential for a market-based approach to provide aflatoxin-safe maize. Using data from Nigeria collected through a Discrete Choice Experiment (DCE), we explicitly explore if maize traders are willing to pay for an aflatoxin-safe product and if willingness to pay varies with the expected (or known) demand for this product.[2] Maize traders in Nigeria provide a unique opportunity to explore this topic because they typically sell to a wide variety of buyers including wholesalers, maize retailers, food companies, small and large feed mills, as well as household consumers. In addition, since low moisture content is often used as an imperfect indicator of the absence of aflatoxin in most studies, we are able to investigate how the WTPs for aflatoxin-safe certification compares to WTP for low moisture content among traders.

This paper makes three key contributions to the literature. First, this is the first study that elicits preferences and willingness to pay (WTP) for an aflatoxin safe label with actors along the supply chain other than producers or consumers. In general, the food safety literature tends to focus on either producers (Kadjo et al., 2016; Kadjo et al., 2019; Udoh et al., 2000), who are located at one extreme end of the supply chain (upstream), or consumers (De Groote et al., 2016; Prieto et al. 2021), who are located at the other extreme end (downstream). This study focuses on maize traders, extremely important actors in the midstream of commodity value chains (often ignored in the literature and policy debates) whose activities affect the welfare of the farmers and consumers that the literature tends to focus on.[3]

Second, this is the first study that simultaneously evaluates how maize traders make trade-offs between an aflatoxin-safe label and different moisture content levels. Using moisture content as a proxy for aflatoxin contamination, some research has looked at traders' demand for low moisture content (Prieto et al. 2021). However, moisture content is an imperfect proxy and does not protect consumers from buying aflatoxin-contaminated maize. Thus, it is worthwhile to investigate traders' preferences and WTPs for aflatoxin-safe label versus moisture content.

Third, this paper contributes to the limited literature on market-based mechanisms for the provision of safe food in developing countries. We design and implement a hypothetical DCE that capitalizes on profit-maximizing behavior of economic agents to explore the possibility of introducing an aflatoxin-safe certification label on tested maize to induce a formal premium for safe maize in the market. The DCE is one of the most popular non-market valuation methods with demonstrated external validity (Hensher et al. 1998, Louviere et al. 1999; Swait and Andrews, 2003; Chang et al. 2009; Brooks and Lusk 2010). It has been applied in various field of applied economics including transport, market research, health, environmental, food economics, and development (Louviere et al. 2010; Caputo et al. 2013; Scarpa et al 2013; Chung and Hensher 2018; Bello and Awudu, 2016; Mahmud et al. 2020). DCE is particularly suited for this study as it allows us to evaluate how traders make trade-offs among multiple attributes simultaneously and to estimate their WTP for an aflatoxin-safe label, which is not yet available in Nigerian food markets. Other studies have used alternative non-market valuation methods such as a Becker–DeGroot–Marschak (BDM) auction to evaluate consumers' WTP for an aflatoxin free tested label (De Groote et al., 2016). However, the validity of a BDM as an incentive-compatible mechanism has been questioned in the recent literature (see Canavari et al. (2019) for an extensive review). In addition, while auctions with

[2] The use of this method is suitable because aflatoxin certification is not yet available on the market, thus ruling out the use of revealed preference data.

[3] A dissertation by Ordonez (2016) looked at maize traders WTP for moisture content and aflatoxin free label in Kenya.

consumers are easier to implement and can still mimic real-life scenarios using small quantities, this is not feasible with maize traders dealing with large quantities.[4]

The paper proceeds as follows. Sections 2 and 3 provide some background on safety concerns along the maize supply chain and discuss potential implications of market channel preferences on trader behavior. Section 4 describes the experiments and procedures while Section 5 discusses the econometric approach. The study results are presented in Sections 6 and 7 concludes.

2. Safety concerns along the maize supply chain in Nigeria

Though often ignored, traders and other actors in the midstream of value chains are key for the efficient operation of food systems. Their actions affect input and output market access as well as the prices received by farmers upstream. Furthermore, their actions affect the price and quality of the final product received by maize processors and consumers downstream (Liverpool-Tasie et al., 2017; Liverpool-Tasie and Parkhi, 2020). In many developing countries, maize wholesalers perform the first quality check post farm gate. Thus, the wholesalers could be instrumental in reducing aflatoxin contamination in maize. They can insist on farmers providing quality output and/or adopt post-harvest strategies such as proper sorting, drying, and storage to reduce the risk of aflatoxin contamination (Wu et al., 2014; Liverpool-Tasie and Parkhi, 2020). However, in the absence of a guaranteed premium for attributes that are not visible, there is no incentive for traders to make such demands on farmers nor incur the extra costs associated with the abovementioned strategies.

Following purchase, maize traders in Nigeria facilitate distribution of the commodity to a wide range of buyers including feed mills, consumers, the food industry, retailers, and other wholesalers (see Fig. 1). These different types of maize buyers typically have different levels of knowledge about and subsequent interest in the quality of maize that they procure. For example, consumers who buy maize for their own consumption tend to care about the moisture content of the grain.[5] High moisture content is associated with high probability of mold growth that is commonly considered unsafe for human consumption. Small feed mills, usually established in neighborhoods catering to households and relatively small livestock farms in the area, tend to have less stringent quality requirements. In turn, a maize trader selling to these buyer categories has no incentive to offer them high-quality maize, including aflatoxin-safe maize.

However, large feed millers and food processors tend to pay attention to the quality of maize they procure. Large feed mills care about the quality of the maize they buy to produce animal feed (typically branded) or to feed their own animals if they are part of a vertically integrated farm.[6] Like large feed mills, food companies care about the reputation of their products among their customers and/or export requirements. Hoffmann and Moser (2017) found that aflatoxin contamination rates were lower for higher-priced maize flour in Kenya because some manufacturers invest more in food safety for fear of losing reputational capital. Food companies in Nigeria also pay attention to the cleanliness and moisture content of the maize they procure. To be assured of cleanliness of the maize they buy, some food companies run a series of tests on the maize before purchasing it. The exact nature of the tests is often unknown to traders but some wholesalers reported having some of their maize rejected because it did not meet the internal standards set by these companies. Many maize wholesalers who buy from other traders (as opposed to farmers), tend to re-sell the commodity (often serving as brokers) to large feed mills and the food industry. Thus, they also tend to be especially particular about the quality of maize they purchase.

The final category of buyers are retailers who buy the maize in bulk from wholesale traders and then sell it in smaller quantities to different types of buyers such as household consumers and small feed mills. In some markets, retailers behave as wholesalers because of the large volumes of maize they supply to some of their buyers. This means that they are likely to deal with customers who care about the quality of the maize they buy, including aflatoxin-safe maize. Their repeated interactions with these buyers create an incentive to protect their reputation by offering them high-quality maize.

The lack of labels guaranteeing that the maize meets certain standards means that many of the retailers, large feed mills, food companies, and other large traders tend to rely on their experience with and the reputation of the trader(s) they procure from for obtaining high quality maize. Furthermore, since maize traders are aware that large feed millers and food companies conduct tests of maize quality prior to disbursing payments they have an incentive to procure good quality maize. The various categories of maize buyers in Nigeria have different quality and maize attribute preference requirements. This serves as the basis of the hypothesis tested in this study:

3. The willingness to pay for aflatoxin-safe maize varies depending on a trader's primary marketing channel and final buyer.

This hypothesis, depicted in Fig. 1, captures the idea that traders who largely sell to other large traders, retailers, the food industry, and large feed mills are likely to pay a higher price premium for aflatoxin-safe maize compared to those who sell to small feed mills and consumers. We first test this hypothesis using the volume of sales that traders make to different channels to categorize them. As an alternative, we estimate traders' WTP for aflatoxin-safe maize categorizing the traders based on if they believe that buyers will pay a price premium versus if the traders actually sell to the buyers who are willing to pay a premium. In line with the incentives of the different marketing channels, we expect that traders who perceive that other traders, food companies, large feed mills and retailers will pay a higher price premium will exhibit a higher WTP than those who do not. The use of traders' perceptions enables us to estimate their WTP for aflatoxin-safe maize even if they do not currently sell to a particular marketing channel. Even if a trader does not sell to any of the four marketing channels of buyers that care about maize quality, they are likely aware of this information from their interactions with other traders and/or their knowledge of how these buyers operate. Thus, we hypothesize that a trader's belief that a buyer will pay a price premium for aflatoxin-safe certification translates into a trader exhibiting a higher WTP compared to one who does not.

4. Experiments and procedures

4.1. Discrete choice experiment: Selection of attributes and attribute levels

In our DCE, respondents were asked to make repeated choices between two maize products and a no-purchase alternative. The maize products were described by various quality attributes, which were selected based on interaction with key informants, through review of the

[4] According to Liverpool-Tasie et al (2017), maize traders in northern Nigeria sell over 430 tons of maize (on average) in the high season and about 300 tons in the low season. Even traders in the south sell about 60 tons (on average) in the high season.

[5] In this study consumers are individuals who buy maize for their own consumption

[6] Unlike the other nodes, feed mills can use a binding chemical which can be mixed with maize during the production of feed to reduce the absorption of aflatoxin by the digestive system of the animal (Johnson, 2017). This is likely to have some implications on how this node will value aflatoxin-safe certification in the study.

Table 1
Attributes and attribute levels in the DCE.

Attributes	Description	Attribute levels
Price*	Purchase price (in Naira/100 Kg)	Plateau state: ₦ 7,800, ₦ 8,800, ₦ 9,800Oyo state: ₦ 10,500, ₦ 11,500, ₦ 12,500
Certification	Aflatoxin safe maize	Maize is certified below 4 ppb for total aflatoxin, not certified
Moisture level	The acceptable level of moisture content to avoid fungal growth is 13%	Low (<13%), medium (14–15%), high (17–19%)
Color	Yellow maize is usually for human and feed consumption while white maize is usually for human consumption	Yellow, White

Note: The price attribute has different values for Oyo and Plateau state because they reflect differences in actual market prices. 4 ppb of total aflatoxin is the allowable level set by the Standards Organization of Nigeria (SON). At the time of the experiment, US$1 was equivalent to ₦345.

literature, and information from a large survey of maize traders conducted in Nigeria between May and June 2017 (see Liverpool-Tasie et al. (2017) for more details on the survey).[7] The final set of attributes for the product includes color, price, moisture content, and an aflatoxin-safe label (see Table 1).

Two levels were chosen for the color of the maize: yellow and white. These are the dominant types of maize in wholesale markets in Nigeria. For the price, we selected three levels for each state: ₦10,500, ₦11,500, and ₦12,500 in Oyo and ₦7,800, ₦8,800, and ₦9,800 for Plateau.[8] These two price vectors reflect differences in actual maize prices across states. Three levels were also chosen for moisture content as shown in McCoy et al. (2016). The first level (low) is less than or equal to 13.0 percent of moisture content which is ideal to avoid fungal growth. The second and third levels are both favorable to the development of mold but capture distinct moisture-content levels. Finally, two levels were selected for aflatoxin-safe certification. One level corresponds to the presence of a label signaling that total aflatoxin content is below 4 ppb[9], and the other is the absence of such a label. Since an aflatoxin safe label does not currently exist in the real market, we created a hypothetical label for the purpose of the experiment.

4.2. Experimental design and survey outline

Basic descriptive statistics from the traders' survey revealed that there is limited differentiation in maize via branding or other maize characteristics. Hence, we implemented an unlabeled design approach. In this approach, respondents were presented with generic product profiles described by a combination of different attributes.

[7] This survey captured the characteristics of the maize being traded, maize traders' demographic characteristics, and their buying and selling behavior throughout the year.

[8] Maize is traded by weight in 100 Kg bags in Oyo and Plateau.

[9] The allowable levels of total aflatoxins (B1, B2, G1, G2) are set at below 4 ppb for human consumption by the Standards Organization of Nigeria (SON) and capped at 20ppb for animal consumption by the United States Food and Drugs Administration (USFDA) (Liverpool-Tasie et al., 2019)

The product profiles were generated using an orthogonal optimal in the difference fractional factorial design, also known as D-optimal design[10](Street and Burgess (2007)). More specifically, two steps were undertaken. In the first step, we used the selected attributes and attribute levels earlier described to perform an orthogonal fractional factorial design. The design resulted in 36 choice tasks only including the first alternative, i.e., a profile of the product including all the attributes. In the second step, we generated the second alternative from the 36 alternatives obtained in the orthogonal design by using the generator (1, 1, 1, 1). This generated a total of 36 choice tasks comprising two experimentally designed alternatives. To reduce the incidence of respondent fatigue, the 36 choice sets were divided into six sets of six choice sets called blocks. Each trader was randomly assigned to one of the six blocks and faced six choice tasks. The six blocks are later pooled at the analysis stage to preserve the properties of the orthogonal fractional factorial design.

Overall, each choice question (or choice task) comprises two experimentally designed alternatives or purchase options (i.e., where each of the attributes are not empty) and one no-purchase alternative or opt-out option. To further improve respondents' understanding of the choice tasks, illustrative visual aids were used. Trained enumerators conducted the DCE in the local language and helped traders understand the meaning of each attribute. A sample choice set is shown in Fig. 2. For each choice task, each respondent had to choose one option from the three alternatives.

In addition to the choice task, we collected information on traders' demographic and socio-economic characteristics, as well as their procurements and sales behavior. The questionnaire administered along with the DCE gathered information on traders' maize-handling practices and knowledge of aflatoxin. The survey and choice tasks were administered with traders in maize markets on days designated as market days. In each market, the first step was to get in touch with the head of the market to explain the objectives of the survey and obtain the necessary permissions. We were given access to all the markets included in our sample. Next, to identify the traders, we called those with active phone numbers (obtained from the list of traders secured through the larger survey exercise (Liverpool-Tasie et al., 2017) and/or asked other traders to help us locate them. Further, to ensure that choices were made under comparable knowledge levels about aflatoxins, each respondent was provided the following information: "*Aflatoxins are mycotoxins produced by a family of molds called Aspergilus. In Nigeria, it is very common in maize and groundnuts. The growth of aflatoxins can start during maize production and continue in storage under certain environmental conditions such as high moisture or if the maize is infested with insects. The contamination is possible without visible signs of the mold. Consumption of food contaminated with aflatoxins has been associated with disease and death in poultry and humans.*" Neutral information of this type was also provided for the other attributes used in the DCE. Providing neutral information about each attribute in respondents' local language helps them recognize the food safety risk even if they did not know about aflatoxins prior to the experiment. Moreover, the majority of traders may have not seen a moisture meter nor understand the meaning of the moisture content measures. However, traders are accustomed to assessing the maize for moisture content using their own technique. As such, enumerators related the different levels of moisture contents to what traders were

[10] This design assumes that all attribute parameter priors are simultaneously equal to zero and defines optimality in terms of the differences in levels for the same attribute across alternatives. We did not implement a pilot experiment to recover priors because of logistical considerations. Furthermore, the maize markets we visited for this experiment have unique characteristics that would not have been captured in a pilot conducted in other markets. The traders in Plateau markets have a unique history of selling maize to large feed mills and the food industry while those in Oyo state cater to the growing number of small feed mills in the region.

	Alternative A	Alternative B	None of these
Price (Naira/100 Kg)	₦9,800	₦7,800	Neither A, nor B. I would not buy
Maize is certified below 4 ppb for total aflatoxin	 Yes	No	
Moisture level	 Low (<13%)	 Medium (14-15%)	
Color	 White	 Yellow	
			CEB1_1

Fig. 2. Example choice task for Plateau state. Note: This is an example choice set. The experiment used a total of 36 choice sets divided in 4 blocks of 9 choices each.

familiar with.

4.3. Data and sample characteristics

The DCE was implemented with maize wholesalers in the two study states (Oyo and Plateau) between February and March 2018. A listing of traders in city and regional markets was conducted in both states. In Oyo state, a listing of the traders in the Ibadan region constitutes the whole sample as there are no other regional maize markets. In Plateau state, the listing exercise identified traders in both city and regional markets. A census of all the traders in city markets was conducted. From the top five regional markets in Plateau state, 30 traders were randomly selected. This resulted in a total of 128 traders in Oyo and 207 traders in Plateau (see Fig. 3). For the DCE, we visited all the traders included in the original trader survey. However, due to non-responses, the sample for this analysis includes 193 traders in Plateau state and 122 traders in Oyo state.

Table 2 describes the socio-demographic characteristics of the respondents in Oyo and Plateau state.

The average age of the traders is 45 and about 60 percent of the sample is male, with significantly more women traders in Oyo state. Just over 80 percent of the traders have an education level above primary school with approximately 13 years of experience. Traders in Oyo state have more experience than their peer in Plateau with about 19 years' experience of selling maize. Traders in Plateau tend to sell large quantities of maize as more than 84 percent register monthly sales above 32 tons compared to only 25 percent in Oyo. Close to all the traders (100% for Oyo and 98% for Plateau) consume some of the maize they procure, but just 18 percent store maize in both states.

Many more traders in Plateau take measures to prevent the growth of mold in maize (61 percent) compared to Oyo (30 percent). The practice of sorting maize, which separates visibly bad grains from good ones, is important for reducing the risks of aflatoxin contamination. Over 90 percent of traders in Oyo sort maize, which is triple the number of traders in Plateau. It should be noted that traders likely sort maize for marketing reasons, rather than aflatoxin concerns. Less than five percent of all traders control the quality of the maize they sell by adding a chemical binder (which is believed to reduce the toxicity of aflatoxin) or ash (which deters attacks by insects and other pests during storage). Additionally, just over 20 percent of all the traders dry the maize they sell, but this average is driven by those in Plateau as only 2 percent of Oyo traders dry maize. Anecdotal accounts collected during the field work suggest that traders in Plateau dry maize because it provides a longer shelf life and fetches higher prices with large feed mills and food industry buyers who favor this attribute due to their processing needs. Very few traders (2%) are aware that moisture content above a certain level is likely to result in aflatoxin growth. This is significantly lower compared to the 16 percent reported among Kenyan traders (Ordonez, 2016). This is not surprising because unlike Kenya, Nigeria has not experienced a documented acute aflatoxicosis outbreak (Wu et al., 2014). The maize sold is rarely tested and a quarter of the traders in Plateau state believe that it is safe for humans to consume moldy maize.

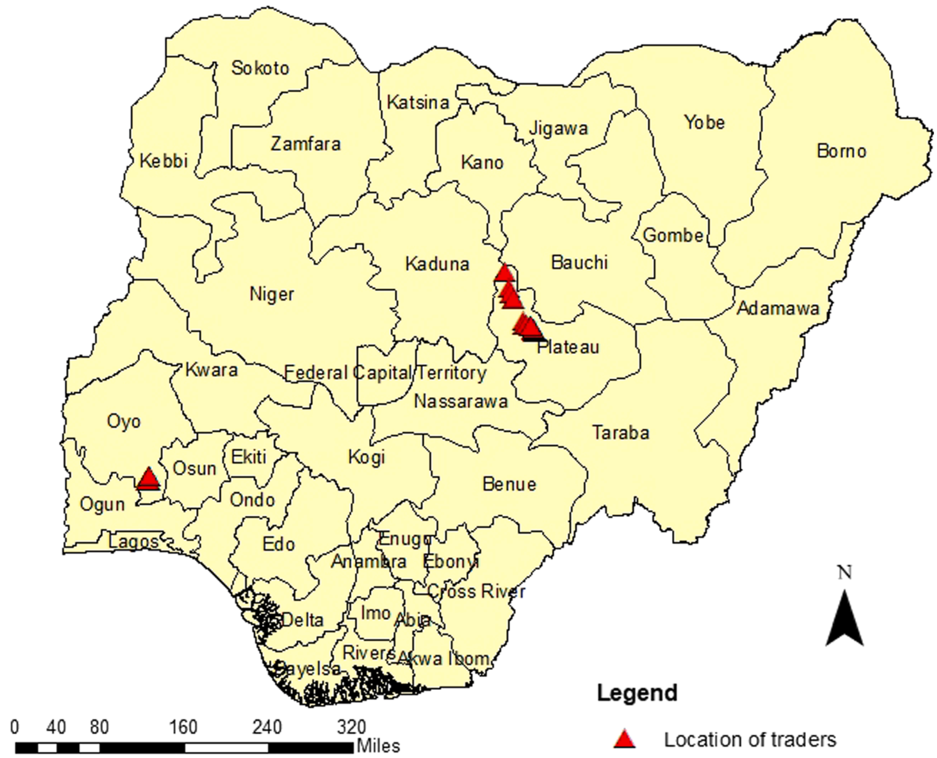

Fig. 3. Map of the location of traders in the two study states.

Table 2
Summary statistics (mean values) of selected participants.

	All	Oyo	Plateau
Age (years)	44.87	44.31	44.91
	(8.34)[a]	(11.16)	(8.07)
Male (0/1)	0.61	0.34	0.64
	(0.49)	(0.47)	(0.48)
Literate	0.84	0.80	0.84
	(0.37)	(0.41)	(0.37)
Number of years selling maize	12.95	18.77	12.47
	(7.96)	(10.51)	(7.52)
Large trader -monthly sales > 32 tons (0/1)	0.80	0.25	0.84
	(0.40)	(0.44)	(0.37)
Consume maize sold (0/1)	0.98	1.00	0.98
	(0.14)	(0.00)	(0.15)
Store maize (0/1)	0.18	0.20	0.18
	(0.38)	(0.40)	(0.38)
Prevent the growth of mold in maize (0/1)	0.49	0.30	0.61
	(0.49)	(0.46)	(0.49)
Sort maize (0/1)	0.34	0.91	0.29
	(0.47)	(0.29)	(0.46)
Know optimal moisture content (0/1)	0.02	0.00	0.02
	(0.13)	(0.00)	(0.14)
Use chemical binder (0/1)	0.04	0.09	0.04
	(0.20)	(0.29)	(0.19)
Use ash (0/1)	0.02	0.02	0.02
	(0.14)	(0.16)	(0.14)
Dry maize (0/1)	0.22	0.02	0.23
	(0.41)	(0.13)	(0.42)
Maize tested before sales (0/1)	0.11	0.00	0.12
	(0.32)	(0.00)	(0.33)
Number of observations	315	122	193

[a] The numbers in parentheses are standard deviations.

Table 3
Knowledge of aflatoxin and maize safety.

	All	Oyo[1]	Plateau
Knowledge of aflatoxin and mold (share of traders)			
Heard of aflatoxin (0/1)	0.10	0.00	0.11
Know causes of aflatoxin build-up in maize (conditional on knowing aflatoxin)	0.47		0.47
Implement steps to control for aflatoxin (0/1) (conditional on knowing aflatoxin)	0.37		0.37
Believe it is safe for humans to consume moldy maize (0/1)	0.23	0.01	0.25
Share of traders who picked the correct answer (for those who heard of aflatoxin)			
Maize infected with aflatoxin will always have high moisture content (T)	0.57		0.57
Maize with high moisture content allows infection with aflatoxigenic mold (T)	0.58		0.58
Maize infected with aflatoxin will sometimes have mold (T)	0.69		0.69
Maize infected with aflatoxin will sometimes have insects or pests (T)	0.72		0.72
Aflatoxin contamination is higher for maize that is stored when it is wet (T)	0.84		0.84
Do you think that it is likely for your maize to have aflatoxin if mechanical shelling is used? (T)	0.07		0.07
Do you think that it is likely for your maize to have aflatoxin if mechanical dehulling is used? (T)	0.07		0.07
In your opinion does aflatoxin negatively influence human health if consumed? (T)	0.74		0.74
In your opinion does aflatoxin negatively influence chickens' health if consumed? (T)	0.70		0.70
Maize infected with aflatoxin will always be discolored (F)	0.07		0.07
Number of observations	315	122	193

Note: Reported statistics are mean values.
[1] Since no trader reported hearing about aflatoxin in Oyo, there is no data for the questions that are conditional on this knowledge.

This might be due to beliefs that if washed off, such maize would be safe after processing and cooking. The differences in means between Oyo and Plateau are statistically significant at the one percent level.

We also collected information on the traders' knowledge of aflatoxin. Eleven percent of the traders in Plateau have heard of aflatoxin

Table 4
Average maize prices.

	All	Oyo	Plateau
	Mean		
High season (November-April) maize prices per 100 kg bags			
Food industry	8,788	12,089	8,517
Feed mill	8,694	11,491	8,518
Retailers	8,776	12,564	8,487
Other wholesalers	8,588	12,131	8,439
Consumers	8,820	13,409	8,376
Low season (May-October) maize prices per 100 kg bags			
Food industry	13,818	8,563	14,306
Feed mill	14,181	9,664	14,472
Retailers	13,535	8,899	13,894
Other wholesalers	13,740	8,417	13,961
Consumers	13,655	10,736	13,928

Note: The number of observations is not reported because it varies for each marketing channel across states. The difference in the mean prices between Oyo and Plateau is statistically significant at the 1% level. The difference in the mean prices between the high season and low season is statistically significant for the pooled data (Plateau and Oyo) and for each state. At the time of the experiment, US$1 was equivalent to ₦345.

compared to none in Oyo. This difference in means is statistically significant at the 10 percent level. Additionally, the percentage of traders in Plateau who had heard of aflatoxin is lower compared to the one reported by other studies. Johnson (2017) reported that 42 percent of poultry producers and feed millers in the sample of a study in Nigeria had heard of aflatoxins. James et al. (2007) found that maize traders' awareness of aflatoxin stood at 44, 6.8, and 11 percent in Ghana, Togo and Benin, respectively. A study in Kenya found that 79 percent of maize traders had heard of aflatoxin (Ordonez, 2016). Conditional on being aware of aflatoxin, 47 percent of Plateau traders know the causes and 37 percent reported undertaking steps to control its growth.

We further assessed traders' knowledge of aflatoxin by asking them a series of questions presented in Table 3.

This section is only relevant to traders in Plateau given that none of the Oyo traders had heard of aflatoxins. In general, the traders who are aware of aflatoxin also know the characteristics that are associated with contaminated maize (except for in a few cases). The fact that one-quarter of the traders believe that moldy maize is safe for human consumption is a public health concern. Very few traders are aware of the link that exists between the method of shelling or dehulling and aflatoxin contamination. In effect, only seven percent of the maize traders recognized that mechanical shelling or dehulling increases the probability of aflatoxin contamination. Additionally, the large majority of maize traders incorrectly associated aflatoxin contamination with maize discoloration.

Table 4 shows maize sales prices during the high season and low season across states. It shows that prices are heterogeneous across different types of buyers in each state.

During the high season when the quantity of maize available is high, maize traders in Oyo receive a premium from sales to consumers. However, in Plateau, feed mills and companies in the food industry pay the highest prices for maize. During the low season, traders in Plateau still enjoy a price premium from food companies and feed mills while those in Oyo receive high prices from the food industry and other wholesalers. In Oyo, the low season prices are surprisingly higher than the high season prices.[11] Informal communication with a few traders in Oyo revealed that in 2017 the period specified in the survey as low season (May-October) coincided with the religious of period of Ramadan when Muslims fast and consume more maize based meals. During Ramadan, the demand for maize increases, thus leading to higher prices.[12] Overall, these patterns seem to indicate that the food industry and feed mills are important buyers for traders of maize in Plateau. This is not the case in Oyo state where maize traders receive a price premium from different types of buyers depending on the season.

5. Econometric analysis

The DCE approach we use is consistent with Lancaster's theory of consumer choice. According to this theory, individuals derive utility from the characteristics or attributes of the goods rather than just from the goods themselves (Lancaster, 1966). The econometric model is based on McFadden's random utility theory, which describes discrete choices in a utility maximizing framework (McFadden, 1974). Let U_{njt} denote the latent indirect utility that trader n will derive from alternative j (one of the three alternatives in each choice task) and in choice situation s (one of the six choice tasks presented to the trader). This utility may be partitioned in an observed or modelled component, V_{njt}, and an unknown stochastic component, ϵ_{njt}, such that:

$$U_{njt} = V_{njt} + \varepsilon_{njt} \tag{1}$$

Assuming V_{njt} is linear in parameters, the functional form of the utility function for alternative j can be expressed as:

$$V_{njt} = \boldsymbol{\beta X}_{njt} \tag{2}$$

where X_{njt} is a vector of observable attributes and attribute levels, and $\boldsymbol{\beta}$ is the corresponding vector of parameters to be estimated; ε_{njt} is an unobserved error term, which is assumed to be independent and identically distributed (iid) extreme value type I. In this study, V_{njt} can be expressed as follows:

$$V_{njt} = ASC + \beta_1 Price_{njt} + \beta_2 Price_{njt} {*} Oyo + \beta_3 Aflatoxin - SafeCertification_{njt} + \beta_4 Color_{njt} + \beta_5 LowMoisture_{njt} + \beta_6 HighMoisture_{njt} \tag{3}$$

where ASC is the alternative specific constant representing the opt-out option; *Price* indicates the maize price in Plateau state; *Price**Oyo* is an interaction term between the price and a dummy variable equal to 1 if the survey took place in Oyo and zero otherwise; *Aflatoxin −SafeCertification* is a dummy variable equal to one if the maize is certified to be aflatoxin-safe, with a level of aflatoxin below 4 ppb; *Color* is a dummy variable equal to one if the maize is yellow and zero otherwise; *Low Moisture* and *High Moisture* are dummy variables equal to one if the moisture level is low and high respectively (medium moisture is the baseline).

Depending on the assumptions about the functional form of equation (2), distributional assumptions of taste variation (traders' preferences over the alternatives), or the distribution of ε_{njt} in equation (1), alternative econometric models can be estimated. In this study, the analysis was conducted using the mixed logit with error component for panel data (MXL-EC) (Train, 2009). The MXL-EC allows us to account for random taste variation and correlation in unobserved factors over time (Train, 2009); as well as correlation across utilities (Scarpa et al. 2005; Scarpa et al. 2007; Caputo et al. 2013). Formally, the unconditional probability of choice in the MXL-EC model for each time period $\mathbf{i} = \{i_1, \ldots, i_T\}$ can be represented as follows:

$$\mathrm{P}\{j\} = \int_{\beta_n} \int_{\epsilon_n} \prod_{t=1}^{T} \frac{e^{V_{njt} + 1(j)\epsilon_{nj}}}{\sum_j e^{V_{njt} + 1(j)\epsilon_{nj}}} f\left(\beta_n, \epsilon_n\right) d\beta_n d\epsilon_n \tag{4}$$

where $V_{njt}$is describes as in (1); 1(j) is an indicator function that takes the

[11] This pattern was observed both in our experiment data and a larger dataset collected from the same markets in Oyo and Plateau states.

[12] As maize is more of a staple in the north, changes in demand due to Ramadan might not be as significant.

Table 5
Estimates from the Mixed Logit Model with error component (MXL-EC).

Coefficients	Estimates	Std. Error	Z-values	P-values
Opt-out	−2.150	0.958	−2.25	0.0001
Price	−0.402	0.107	−3.75	0.0002
Price Oyo	0.178	0.043	4.04	0.0001
Error component				
Mean	0.000	–	–	–
Std. dev.	3.116	0.335	9.31	0.0000
Aflatoxin-Safe Certification				
Mean	2.643	0.314	8.41	0.0000
Std. dev.	2.725	0.323	8.43	0.0000
Yellow maize (color)				
Mean	0.069	0.204	0.34	0.7329
Std. dev.	0.812	0.343	2.37	0.0179
Low moisture				
Mean	3.165	0.335	9.43	0.0000
Std. dev.	3.191	0.419	7.62	0.0000
High moisture				
Mean	−2.929	0.399	−7.34	0.0000
Std. dev.	2.795	0.578	4.83	0.0000
N	1,890			
Log likelihood	−1091.4			
χ^2	1969.9			

Note: Medium moisture content is the reference. Models were estimated using NLOGIT 6.0. 1000 Halton draws were used to estimate the MXL-EC model.

value of 1 for the experimentally designed product profiles and zero for the opt-out option; ϵ_{nj} is zero-mean normally distributed respondent-specific error component, $f(\beta_n, \epsilon_n)$ is the probability density function of the vector random coefficients $<\beta_n, \epsilon_n>$. The sample log-likelihood based on equation (4) lacks a closed-form solution. Following Train (2003), the parameters of the model were estimated by simulated maximum likelihood estimation techniques.

Estimates from (4) can be used to calculate marginal WTPs for the experimentally designed attributes. Following the procedures described in Train (2009: 259–281) and discussed in Hensher, Rose and Green (2015: 646–650), we derived individual-level, conditional parameters of WTPs for aflatoxin safe certification and moisture content across marketing channels.

6. Results

6.1. Trader preferences for maize attributes

Table 5 reports coefficients from the MXL-EC which allows for correlated random coefficients and an error component.[13]

As predicted by economic theory, higher prices are associated with negative utility (disutility) and a lower probability of purchase. This effect is statistically significant at 1% level. The coefficient on the interaction term between price and the trader being in Oyo state (β_2) is positive and significant, indicating that traders in Oyo derive less disutility from higher prices than their counterparts in Plateau. The coefficient on the alternative specific constant for the opt-out option shows that the utility derived from the no-buy alternative is on average lower than the utility derived from the two experimentally designed alternatives. This means that the majority of the traders preferred picking one of the two experimentally designed alternatives over not choosing anything. Both low moisture content and aflatoxin-safe certification are statistically significant at 1% indicating that traders' utility increases when these attributes are reported on food products.

Though the marginal utility obtained from low moisture content is the highest (3.2 percentage points), the presence of aflatoxin-safe certification still increases utility by 2.6 percentage points. While higher utility from low moisture content is not surprising (since traders generally tend to use moisture content as a proxy for the quality of maize), these results indicate that traders derive additional positive marginal utility from an aflatoxin-safe certification. Since low moisture-content maize can still be aflatoxin-contaminated, this implies that the introduction of aflatoxin-safe certification could provide an additional signal of quality to buyers and likely improve the quality of the maize available in the market. As expected, high moisture content provides a significant disutility to traders. The negative coefficient estimate is different from zero at 1% confirming that moisture level is used as a proxy for maize quality.

Further, while we do not find a significant effect of color on trader utility, the standard deviations of all the other attributes are also statistically significant. This significance suggests that there is heterogeneity around the mean parameter estimate over the sample of traders. Following Train et al. (2009), we also estimate the share of individuals with negative preferences for each of these attributes.[14] We obtain the amount of dispersion that exists around the sample population. It is not surprising that 85 percent of traders dislike high moisture content. Maize wholesalers seem to treat the aflatoxin safe label and low moisture content similarly. To illustrate, approximately 15 percent of them dislike these two attributes. This could also be an indication that traders are ready to accept aflatoxin-safe certification as a plausible alternative to their informal means of measuring moisture content.

To further evaluate preference heterogeneity, we examine the estimated Cholesky matrix, and implied correlation coefficient matrix (See Table A2 and Table A3 in the appendix).[15] Results from the Cholesky matrix indicate that preference heterogeneity persists, even after allowing for cross-correlations across attribute parameters (as evidenced by the statistical significance of the non-zero diagonal elements). Significant below-diagonal elements in the Cholesky matrix suggest the existence of cross-correlations among the random parameter estimates that otherwise would be confounded within the standard deviation parameter estimates. From the implied correlation matrix, for example, the correlation between aflatoxin-safe label and low moisture content is positive, while the correlation between aflatoxin-safe certification and high moisture content is negative. This indicates that those who value aflatoxin-safe certification tend to like maize with low moisture content. Further, preferences for yellow maize are positively correlated with preferences for low moisture content but negatively correlated with preferences for high moisture content. This further attests to the importance of low moisture content.

6.2. Traders' WTP for maize attributes across marketing channels

6.2.1. Aflatoxin-safe certification

The study hypothesis is that the willingness to pay for aflatoxin-safe maize varies depending on a trader's primary marketing channel and final buyer. Table 6 reports traders' conditional marginal WTP (mean

[13] We took the following approach for model selection. First, using both the pooled (both states) and segmented (each state) samples, we estimated the following models: multinomial logit model, mixed logit model, mixed logit model with error component, and mixed logit model with error component and correlated random coefficients. Second, we used the conventional model fit criteria (BIC, AIC, and LL) to select the preferred model (see Table A-1 in the appendices). Consistent with the literature (Scarpa et al. 2005, Caputo et al. 2016), the mixed logit model with error component and correlated random coefficients was selected as preferred model (MXL-EC). Table 5 reports only the estimates of the MXL-EC model from the pooled data set as results between the segmented and pooled samples were consistent.

[14] We estimate these statistics using the mean and standard deviation for each attribute in a cumulative distribution function.

[15] In the presence of more than one random parameter as it is the case here, the standard deviations are no longer independent. The Cholesky matrix decomposes the standard deviations for each random parameter (Hensher et al., 2015).

Table 6
Traders' WTP for certification across main marketing channels.

	All	Other traders	Small feed mills	Large feed mills	Food industry	Retailers	Consumers
Oyo and Plateau							
Mean	8,810	11,980	4,291	5,794	7,418	8,307	7,807
	(447)	(780)	(842)	(1,704)	(1,090)	(736)	(2,420)
Median	7,931	10,741	3,773	6,037	6,962	7,388	3,732
N	278	101	37	14	46	67	13
F-test[a]: 0.0000							
H-test[b]: 0.0001							
K-test[c]: 0.0000							

Note: The WTP values are per 100 kg bag of maize. Numbers in parentheses are standard errors. We also implemented a Bonferroni multiple comparisons test and found that the difference of the mean WTP is statistically different between: i) traders and small feed mills at the 1% significance level; ii) traders and large feed mills at the 5% significance level; iii) traders and food industry at the 1% significance level; iv) traders and retailers at the 5% significance level; v) small feed mills and retailers at the 10% significance level. At the time of the experiment, US$1 was equivalent to ₦345.

[a] P-value from F-test testing the null hypothesis of equality of means across marketing channels
[b] P-value from the Kruskal-Wallis H test testing the null hypothesis of equality of means across marketing channels
[c] P-value from K-sample test testing the null hypothesis of equality of medians across marketing channels

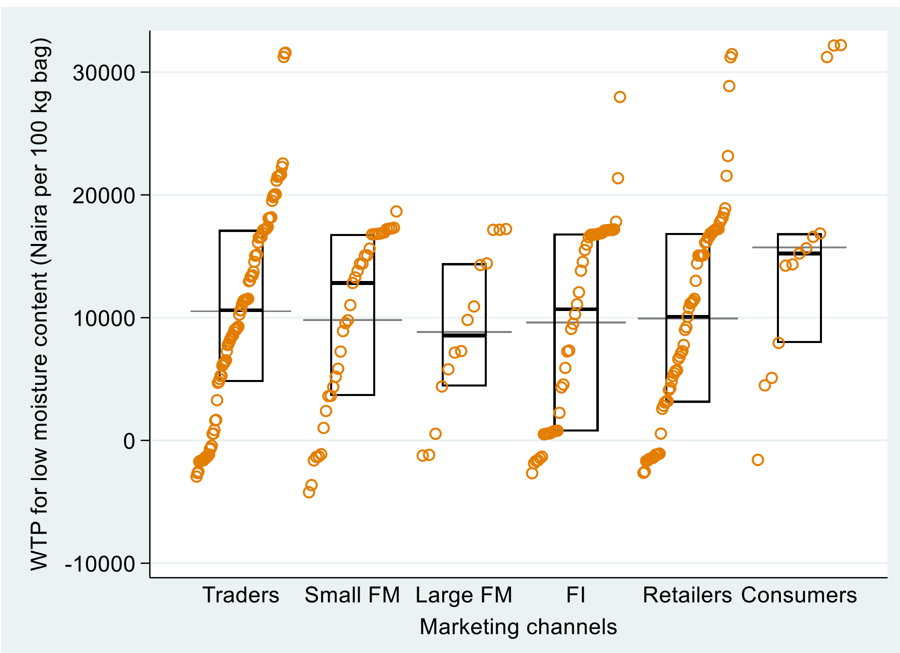

Fig. 4. Graph of WTP for low moisture content *by marketing channel (pooled)*. Note: Boxes show median and quartiles. The added bars are the means. Small FM is small feed mills, large FM is large feed mills, and FI is food industry. The median (mean) WTP values in Naira for different purchaser groups are as follows: 18,855 (17,416) for Traders, 12,093 (10,594) for small FM, 8,238 (9,458) for Large FM, 14,367 (13,154) for FI, 11,387 (14,193) for Retailers, and 19,846 (23,290) for Consumers. The means and medians are not statistically different across marketing channels. We also checked for statistically significant differences by removing outliers and the results remain unchanged. At the time of the experiment, US$1 was equivalent to ₦345.

and median) for aflatoxin-safe certification[16] based on their main marketing channels for both states.[17]

We find consistent evidence that the marginal WTP for aflatoxin-safe certification varies significantly across marketing channels. To illustrate, using the median values (which are less sensitive to outliers), traders who sell to other traders, retailers, the food industry, and large feed mills are willing to pay the highest price premium (₦10,741, ₦7,388, ₦6,962, ₦6,037 respectively) for aflatoxin-safe certification.[18] Traders who sell to consumers, on the other hand, have the lowest WTP for aflatoxin-safe certification. The p-value from the K-sample test confirm that these median values are statistically different from each other. Overall, these results are aligned with our main hypothesis; traders who sell to buyers with stringent quality requirements will pay a higher price premium for aflatoxin-safe maize compared to those who sell to consumers and small feed mills.

Several key points stand out about the differences in marginal WTP for aflatoxin-safe certification across marketing channels. First, the marketing channel "other traders" is largely composed of agents who resell the maize to large feed mills and the food industry. This likely explains the high magnitude of the WTP we observe for this marketing channel. Field visits to the maize markets and informal exchanges with agents and maize brokers revealed that large feed mills and the food industry are very particular about maize quality. They run a battery of tests on the maize bought from agents. Any lot of maize that fails the tests is subsequently returned to the agent who often sells it at a lower price to smaller feed mills or pig breeders. Many maize traders also shared that they tend to sell their highest quality maize to agents who buy large quantities of grain for feed mills and companies in the food industry. Second, maize wholesalers who sell to retailers exhibit a high WTP for aflatoxin-safe maize; similar to those of traders selling to the food industry. While many retailers sell small quantities of maize directly to consumers, some also sell large quantities of maize to other traders doubling as wholesalers. This might explain their high WTP for

[16] Conditional marginal WTPs for aflatoxin safe certification across States were calculated using the estimates from Table 5 following the procedures described in Train (2009: 259–281) and discussed in Hensher, Rose and Green (2015: 646–650).
[17] The results are consistent with the separate states.
[18] Though the results in table 6 are for the pooled sample, they are consistent with the separate results for each state.

Table 7
WTP for aflatoxin-safe certification as a function of trader perception that a buyer will pay a price premium.

	Traders who perceive that food industry and large feed mills will pay a premium	Traders who do not perceive food industry and large feed mills will pay a premium	Traders who perceive that other traders and retailers will pay a premium	Traders who do not perceive other traders and retailers will pay a premium
Oyo and Plateau				
Mean	10,752	7,743	10,659	7,425
	(752)	(486)	(639)	(522)
Median	10,241	6,571	10,741	5,751
N	86	229	111	204
F-test[a]	0.001	0.0002		
H-test[b]	0.001	0.0001		
K-test[c]	0.001	0.000		

[a] P-value from F-test testing the null hypothesis of equality of means across marketing channels.
[b] P-value from the Kruskal-Wallis H test testing the null hypothesis of equality of means across marketing channels.
[c] P-value from K-sample test testing the null hypothesis of equality of medians across marketing channels At the time of the experiment, US$1 was equivalent to ₦345.

aflatoxin-safe maize as was found for the "other traders" group.

6.2.2. Moisture content

We explore how WTP for moisture content (the current main proxy for maize quality in Nigerian maize markets) varies across marketing channels.[19] The results reported in Fig. 4 show that the WTP values differ across marketing channels. More specifically, we find that the WTP for low moisture content is highest for traders who sell to consumers with a median value of ₦19,846 (US$ 57.5) per 100 Kg bag. While the mean differences are not statistically significant across channels, the order of magnitude is consistent with anecdotal evidence that the attribute consumers know and care more about (as a measure of quality) is the moisture content. This evidence suggests that final markets do not matter much when it comes to the moisture content as traders are willing to pay a significant price premium for low moisture content regardless of the final market. This is likely related to the fact that the moisture content attribute is a search attribute. Hence, individuals are able to inspect the levels of moisture across all levels of the value chain. In the case of an aflatoxin-safe label, on the other hand, we found statistically significant differences between traders' WTP depending on the channel they were in. This difference may be explained by labels being credence attributes invisible to the buyer; therefore, trust and reputation play a crucial role in the buying process and thereby play a crucial role in the final markets.

6.3. The role of traders' perception

As an alternative approach to test for heterogeneous WTP by maize traders across market channels, we examine WTP for aflatoxin-safe certification based on traders' perception that a buyer would be willing to pay a price premium for aflatoxin-safe maize. During the field survey, we asked traders to rank who they believed would be willing to pay an extra price premium for certified aflatoxin-safe products, using a Likert-scale measure from 1 (do not firmly believe) to 5 (firmly believe). We split the sample of traders into two groups; those who firmly believe (meaning they picked 5 on the Likert scale) that a buyer from a particular market channel (consumer, small feed mills, other traders, retailers, food industry, and large feed mills) would be willing to pay an extra price premium, and all other traders in the sample (i.e., those who did not choose 5 on the Likert scale). Table 7 presents the results.

As found with the categorization based on the volume of sales, Table 7 shows that traders who perceive that the food industry and large feed mills would be willing to pay a price premium for aflatoxin-safe maize exhibit a WTP that is ₦3,009 ($US 8.7) higher than their peers who do not share that perception.[20] This result suggests that the traders' behavior is conditioned by what they believe about the final buyer. That is, if customers begin to value the aflatoxin-safe certification, then traders will have an incentive to provide aflatoxin-safe maize in Nigerian markets.

Next, we focus on large buyers who purchase maize for resale. We make the same comparison between 1) traders who firmly believe (meaning they picked 5 on the Likert scale) that other wholesale traders and retailers would be willing to pay an extra price premium, and 2) those traders who did not choose 5 on the Likert scale. Again, the results for both states provide suggestive evidence that traders behave according to what their buyers demand. Traders who perceive that other wholesalers and retailers will be potential buyers of an aflatoxin-safe certification label are willing to pay approximately ₦3,234 (US$ 9.4) more than their peers who think otherwise. Again, this story is consistent across states.

7. Conclusion and policy implications

This paper uses a DCE to estimate maize traders' willingness-to-pay (WTP) for aflatoxin-safe maize in Nigeria. This work departs from previous preference studies in three important ways. First, while previous studies have focused on subgroups (nodes of the supply chain) such as farmers and consumers, this is one of a few studies focusing on maize traders, key intermediaries between millions of maize producers and millions of maize food and feed consumers. To explore the potential of a market-based approach to dealing with food safety challenges associated with maize, the study exploits the fact that maize traders sell to different categories of buyers (with different preferences for product attributes) to estimate the heterogeneous WTP for aflatoxin-safe certification of maize.

Second, we estimate WTP for aflatoxin-safe maize based on the traders' perception (subjective knowledge of what different marketing channels value, even if they do not sell to that channel) about a category of buyer's willingness to pay a price premium for aflatoxin-safe maize. Third, we evaluate maize traders' WTP for low moisture content, an attribute that is sometimes used as a proxy for aflatoxin contamination.

[19] Anecdotal evidence from the field reveals that there are both formal and informal mechanisms through which traders check moisture content in Nigeria. These include the traditional moisture meter named the "chukman". Traders use the "chukman" to assess moisture levels, by observing the flow of maize. When the flow is slow it means there is high moisture level, when the flow is high, it means there is low moisture level. Additionally, some buyers use modern moisture meters to measure the level of moisture content before buying the maize.

[20] The results across states are presented in the appendix and consistent with the pooled results. For space consideration we focus on the pooled results in the text.

The inclusion of both low moisture and aflatoxin in the DCE enabled us to separately evaluate preferences for these two attributes. This is the first study we are aware of to do this.

We find strong evidence that maize traders respond to the attributes of their customers and these results are consistent across study states and analytical approaches. Different maize buyers have different preferences for maize quality depending on their knowledge, use of the product and or need to maintain brand reputation. In line with our hypothesis that maize traders' willingness to pay for aflatoxin-safe certification will vary depending on the preferences of their final customers for such attribute, we find that traders selling to other traders, large feed mills, food companies, and retailers exhibit a higher WTP for aflatoxin-safe certification compared to those who sell to small feed mills and consumers. These results are maintained whether we categorize traders based on their volume of sales to a marketing channel or their perception that a marketing channel will be willing to pay a price premium. Maize traders who believed that other traders, retailers, large feed mills, and food companies would be willing to pay a price premium for aflatoxin-safe maize exhibited a higher WTP for aflatoxin-safe maize compared to others.

Consequently, our findings suggest that maize traders in Nigeria will purchase aflatoxin-safe maize if they know or believe that there is a market for it. The differences in WTP for aflatoxin-safe certification among different traders based on their main buyers suggest that an aflatoxin-safe certification scheme would currently appeal to traders who cater to large buyers such as food companies and large feed mills. However, since traders respond to the attributes that their customers care about, this implies that improved consumer awareness about the dangers of aflatoxins in their food could create a demand for an aflatoxin safe product and consequently increase the WTP among traders serving consumers.

These findings have important policy implications for the functioning of maize markets in Nigeria and other countries facing similar situation with poor regulation and food safety challenges. From a public health point of view, the use of moisture level as a proxy for aflatoxin contamination is not ideal. Consumers already value moisture level in their buying decisions and can inspect the moisture level at every level in the value chain, thereby not impacting final markets. Though moisture testing is relatively easier and cheaper than testing for aflatoxins, using moisture as a proxy does not protect consumers from buying aflatoxin contaminated maize. The consumers are still exposed to the negative health impacts that are associated with the consumption of aflatoxin-contaminated maize. Thus, efforts to create awareness and demand for aflatoxin safe foods is still necessary. In addition, our results indicate that traders still derive additional positive utility from aflatoxin safe certification; indicating that aflatoxin-safe certification likely provides an additional signal of quality to buyers.

From a policy perspective, the introduction of an aflatoxin-safe certification scheme should be accompanied by an information campaign highlighting the negative health impacts of the toxin. An information campaign would increase the aflatoxin-safe certification scheme's reputability and thereby consumers' trust in the scheme. This increase in trust would ultimately increase consumer awareness and would influence their decision to purchase maize. Because of the dire health implications of consuming foods with high levels of these mycotoxins, the ideal solution for society is the development and strict enforcement of minimum acceptable standards. A purely market-based approach will not remove dangerous products from markets likely to the detriment of the poorest as shown by Hoffmann et al. (2020), who found that food companies have limited profit-driven incentives to comply with food safety regulations in the absence of enforcement.

Finally, further research is needed on how the costs associated with aflatoxin certification compare to the willingness to pay for such certification by traders (and other economic agents) and how this varies with the preferences of their buyers. This will inform the kind of policy support that might be necessary prior to the full development of a market for aflatoxin safe food products.

CRediT authorship contribution statement

Awa Sanou: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing - original draft, Writing - review & editing, Visualization. **Lenis Saweda O. Liverpool-Tasie:** Conceptualization, Funding acquisition, Project administration, Supervision, Writing - original draft, Supervision, Writing - review & editing, Visualization. **Vincenzina Caputo:** Conceptualization, Project administration, Methodology, Supervision, Writing - original draft, Supervision, Writing - review & editing, Visualization. **John Kerr:** Conceptualization, Supervision, Writing - original draft, Supervision, Writing - review & editing, Visualization.

Appendix

(See Tables A1-A3)

Table A1
Comparison of information criteria.

Model	Log-Lik	Parameters	BIC	AIC
MNL	−1429.8	7	2882.5	2873.5
MXL	−1280.1	11	2596.3	2582.2
MXL-EC	−1154.4	12	2269.5	2332.8
MXL-EC with correlation	**−1091.4**	22	**2110.7**	**2226.8**

Table A2
Correlation matrix from MXL-EC with correlation model.

	1	2	3	4	5
Aflatoxin-safe certification (1)	1.000	0.81	0.598	0.167	−0.176
Color (2)		1.000	0.187	−0.122	0.101
Low moisture (3)			1.000	0.803	0.128
High moisture (4)				1.000	0.563
ERC (5)					1.000

Table A3
Cholesky matrix from MXL-EC with correlation estimates.

	1	2	3	4	5
Aflatoxin-safe certification (1)	2.726***				
Color (2)	0.61**	0.472			
Low moisture (3)	1.907***	−1.648***	1.957***		
High moisture (4)	0.468	−1.241**	2.159***	1.180**	
ERC (5)	−0.549	1.309**	2.287***	1.567***	0.106

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