Incomplete information and product quality in rural markets: Evidence from an experimental auction for maize in Senegal[1]

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Abstract

Quickly drying grains to a low, safe moisture content is key to increasing their storability and limiting the spread of aflatoxins, potent carcinogenic toxins for children, adults, and livestock. The extent to which people can observe and value moisture content in grain matters because it determines whether markets create the appropriate incentives for actors to dry maize to a safe level for storage. To increase our understanding of this issue, we use an experimental auction with traders and consumers in southern Senegal to elicit participants' willingness-to-pay for maize of varying moisture content. Our results suggest that participants are willing to pay more for drier maize, but are uncertain of their ability to detect moisture content without it being labeled through external verification. When maize is labeled with its moisture content, participants are willing to pay 22 percent more for drier maize that is safe to store. This includes a quality premium that more than compensates for the difference in density between wet and dry maize. Labeling maize with its moisture content, or providing market agents with their own reliable way to determine moisture content, could incentivize more parties to trade drier, healthier and safer maize.

JEL classification codes: O130, O170, Q130, Q180

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Maize is the most widely produced and consumed cereal crop in sub-Saharan Africa (SSA), and comprises the majority of calories eaten by millions of low income smallholder farm households. While an expansive literature documents the challenges associated with boosting yields, much less research has been conducted on farmers' and traders' incentives and constraints to drying and storing high quality, safe maize after it is harvested. In this paper we use experimental auctions to measure individuals' willingness to pay (WTP) for maize of various moisture contents, both when the maize is unlabeled and labeled with its moisture content, and draw implications for rural grain markets in developing countries.

As a staple crop, maize needs to be stored over long periods of time after harvest, for both home-consumption and sale. One of the key necessities for safely storing maize is to dry it within three days of harvest to 13.0 percent moisture content (MC) or below (Oyebanji and Efiuvwevwere, 1999). Doing so is critical because fungi thrive in maize stored above this threshold, including several species that produce aflatoxins (notably *Aspergillus flavus*). Aflatoxins are invisible, tasteless, but potent toxins associated with negative effects on the immune systems of humans and animals, including higher stunting rates for children, liver cancer, and long-term negative health and cognitive consequences (Liu and Wu, 2010, Williams, et al., 2004). Chronic aflatoxin exposure is difficult to measure, but is believed to significantly affect the disease burden in developing countries (Khlangwiset, et al., 2011). Recent studies point to a high prevalence of aflatoxins in maize produced by smallholder farmers in SSA. For example, 29 percent of maize samples collected from over 1,500 smallholder farmers in southern Senegal have aflatoxins levels above the United States limit of 20 parts per billion (Prieto, et al., 2017). In the same region, Ileleji et al. (2015) also record that 26 of 88 maize samples (30 percent) taken randomly from post-harvest cobs or shelled corn contained aflatoxins.

Maize producers' and traders' incentive to dry maize to safe levels hinges on several factors. One key factor is the observability of maize moisture content, yet whether maize moisture content is observable by producers, traders, and consumers in developing countries is unclear.[2] Maize buyers in SSA traditionally rely on touching, biting, and/or shaking the kernels to determine MC (among other grain attributes), but the accuracy of these methods has not been tested to our knowledge. Grain MC can be reliably determined in two ways: (i) using a moisture meter, a tool prohibitively expensive for smallholder farmers and small- or medium-size traders in SSA, or (ii) by measuring both weight *and* volume of grains.[3] In many parts of SSA, however, maize is typically traded based on weight *or* volume, but rarely both.[4] When information on maize MC is incomplete there is no market incentive to dry it, because wetter maize kernels are heavier and occupy more space (keeping volume and weight constant, respectively), thus fetching a higher price when traded on weight or volume alone.

The present article uses an experimental auction with maize consumers and traders in southern Senegal to begin addressing potential market inefficiencies that may lead to the presence of unsafely-wet maize in rural markets of SSA. Specifically, we measure maize consumers' and traders' WTP for maize of various MCs, presented as both unlabeled and labeled with the precise MC, measured using a moisture meter.[5] In doing so, we address the following four questions. (1) Do consumers and traders *value* drier maize? (2) If they value drier maize, does the higher value constitute a "quality premium," defined as willingness to pay more for

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[2] For example, Fafchamps, Hill, and Minten (2008) list maize moisture content as an unobservable attribute in Table 1 of their article, and as easily observable later in the same article's text. This is an example of the confusion surrounding the observability of moisture content, and which parties (traders, consumers, and/or producers) can observe it.
[3] We describe in detail in Appendix A how mass and volume together can be used to determine grain moisture content.
[4] Anecdotal evidence suggests this is true in Senegal, where we conducted our fieldwork, and in Kenya, Malawi, Tanzania, and Benin.
[5] Throughout this article, "labeled" refers to maize labeled with its moisture content, and not any other attribute.

drier maize than the difference in density between wet and dry maize would dictate? (3) Are traders and consumers confident in their ability to determine the MC of maize on their own using traditional methods? (4) Do traders and consumers differ in their ability to detect maize MC with traditional methods?

The literature on the link between food safety, market participation and willingness to pay for unobservable grain quality in developing countries is very sparse. A few recent studies have used auctions to measure price discounts for clearly-observable attributes such as insect damage in stored maize. For example, smallholder farmers in Benin discounted maize price by three percent for a 10 percent increase in visible insect damage on average; the discount was more pronounced in the harvest season, compared to the lean season when maize becomes scarce and quality premiums disappear (Kadjo, et al., 2016). To our knowledge, the only other auction-based study to estimate WTP for maize MC, an unobservable or partially-observable attribute, finds that Kenyan traders are willing to pay 2.7 percent more for maize at safe-for-storage MC levels (below 13.0 percent) than for maize of unknown moisture (Ordonez, 2016).

The present article also contributes to the information asymmetry literature. If different market actors have different abilities to detect MC in unlabeled maize, or if there is incomplete information in which neither party can reliably detect MC, the prevailing price will be for the average quality on the market, which is analogous to the "lemons market" described by Akerlof (1970). In this scenario, good quality, dry, safe (aflatoxins-free) maize is absent from the market. This issue has been investigated recently for onions in Senegal by Bernard et al. (2017), who find that provision of information in the market reduces urea-based fertilizer use (which increases onion size but lowers quality due to high water content) by 9 percent. Hoffmann and Gatobu (2014) also find that buyers in rural Kenyan markets are willing to pay a 20 percent price premium for own-grown maize over maize of similar visible quality, and an 11 percent premium for maize from a neighbor vs. maize from an unknown source. They attribute this WTP difference to asymmetric information and potential aflatoxins contamination of marketed maize, and further suggest that the finding explains in part why market participation is low among smallholders in sub-Saharan Africa.

Our article adds to the existing literature in four main ways. To our knowledge, we are the first to (i) empirically document the reliability of local grain moisture detection methods; (ii) separately identify density and quality premiums for grains; (iii) directly test for the differences between traders' and consumers' ability to determine grain MC and its effect on their WTP; and (iv) use experimental incentive-compatible auctions. Such auctions minimize bias and increase response validity compared to cross-sectional studies of grain moisture content and individuals' perception of moisture content and its impact on grain quality, and provide a needed complementary social science perspective on studies of the technical merits of various approaches to controlling moisture content (e.g., Suleiman, et al., 2018, Tubbs, et al., 2017, Walker, et al., 2018).

Our results indicate that both traders and consumers in southern Senegal value drier maize, as they are willing to pay a higher price for drier maize that is labeled with its moisture content. Both traders and consumer place a quality premium (i.e. their higher WTP for drier maize more than compensates for the value of the additional number of maize kernels per unit of weight or volume) on drier maize when the maize is labeled, but not when it is unlabeled. For unlabeled maize they are only willing to pay for the density difference in maize of different moisture contents. This suggests that local MC detection methods, while partially valid to differentiate MC, are not reliable- or precise-enough to give buyers complete confidence in the moisture content level of the maize they are purchasing. Thus, developing and diffusing a low-cost, reliable device for detecting MC in maize would improve maize markets in developing countries and could lead to a large reduction in aflatoxins-contaminated maize, and a corresponding improvement in child, adult, and animal health.

Background

In this section, we first provide background information on how maize becomes contaminated by aflatoxins and the role of moisture content in aflatoxins contamination and spread. Then we explain the difference between density and quality premiums in detail.

Moisture content and aflatoxins

An estimated 4.5 billion people in developing countries are chronically exposed to aflatoxins (Williams, et al., 2004). In countries where there is no enforced regulatory limit on aflatoxins, households may not be aware of aflatoxin or have the means to prevent it (Hell, et al., 2000, James, et al., 2007). Prieto, Bauchet, and Ricker-Gilbert (2017), for example, report that without the benefit of information from local extension agents on post-harvest practices, only 18 percent of households in southern Senegal are aware of aflatoxins and of their toxicity.

Maize kernels can be contaminated with aflatoxins in two ways. Contamination can happen in the field prior to harvest, if fungi responsible for the toxins are present in the soil or in the plants. Proper drying and storage after harvest cannot eliminate this contamination, but can stop its spread. Kernels can also come in contact with aflatoxins-producing fungi when dried directly on the bare ground, either in the field or at the farmer’s house. Drying off the bare ground is the most efficient aflatoxins-reduction strategy for most smallholder farmers (Hell, et al., 2008).

Once a kernel is contaminated, the next best option is to reduce or ideally stop the spread of aflatoxins to other kernels. This can be done by storing the maize at 13.0 percent MC or below, which deprives the fungi of the moisture it needs to grow and has been shown under laboratory and strictly controlled field conditions to reduce aflatoxins spread (Ng'ang'a, et al., 2016, Williams, et al., 2014).

Density and quality premiums

Since water is less dense than the materials that give a maize kernel its nutritional value (flour, bran, oil, etc.), grain density is directly related to moisture content. In turn, density (d) equals mass (m) divided by volume (v), so that if one measures both the weight and volume of a certain quantity of maize, one can reliably and precisely determine grain moisture content. For example, maize traded in the United States is standardized to a 56-pound bushel: maize weighing 56 pounds and occupying one bushel of volume has a 15.5 percent MC. See Appendix A for more information on these calculations.

A higher WTP for drier maize may therefore account for the fact that a certain mass of drier maize contains more kernels than the same mass of wetter maize. We label this difference the "density premium." Using the d=m/v relationship, we determine that the density premium for maize at 15 percent MC (the middle point of the 14-16 percent MC range we label "medium MC") as compared to 18 percent MC maize (the middle point of the 17-19 percent range we label "high MC") is 5.9 percent. In other words, medium-MC maize is 5.9 percent heavier than high-MC maize. Similarly, the density premium for 13 percent MC maize (the upper bound of the 13 percent-and-below range we label "low MC") versus 15 percent MC maize is 4.3 percent (Appendix A). The density premium for low-MC maize as compared to high-MC maize is 10.5 percent.[6] Note that maize density is nonlinear in moisture content, so that the density premium is also non-linear. The sum of the low-medium and medium-high density premiums is 10.2 percent: the 0.3 percentage point difference with the low-high density premium (10.5 percent) indicates that the effect of the non-linearity is small over the range of MC that we consider. In analyses of the density and quality premiums, we take into account the non-linearity by analyzing premiums from low to medium and from medium to high MC separately.

We characterize any difference in WTP for the different maize MC levels *above the density premium* as a "quality premium," (ie: a higher price that buyers are willing to pay because they value drier maize). The quality premium could reflect the improved storability of drier maize, the savings arising from not needing to dry maize further before re-selling it (for traders), and/or awareness of the dangers of aflatoxins and their growth in wetter maize.

Methods

We used experimental auctions to elicit the homegrown values that consumers and traders in southern Senegal place on maize of varying MC, while controlling for any other perceived variation in attributes of the maize.[7] Our auctions used both a second-price mechanism and aBecker-Degroote-Marschak (BDM) mechanism to elicit participants' true values for six grades of maize: labeled and unlabeled maize that varied by three MC levels (Becker, et al., 1964, Vickrey, 1961).

[6] It is slightly different from the sum of the two premiums above (10.2 percent) because density is non-linear in moisture content (Appendix A).

[7] Participants bring homegrown values into an experiment for real-world goods, vs. induced values imposed by the experimenter (Lusk and Shogren 2007).

Our experimental auctions took place over 16 days in the Kolda region of southern Senegal from October 26 to November 12, 2015. This coincides with the harvest season, in which buyers might expect more variation in MC from maize that is marketed. We randomly sampled 166 maize traders and 182 consumers, for a total of 348 individuals in our dataset.[8] Traders are anyone who buys and re-sells maize, (typically directly) from producers for sale directly to consumers.

Sample

We used a simple stratified sampling method, randomly selecting auction participants from the seven largest urban and rural markets in the Kolda region (Kolda, Diaobé, Vélingara, Manda Douane, Saré Yoba, Medina Yoro Foulah, and Bayoungou). We do not know of any data on attendance to these markets, but the estimated population of the Kolda region in 2017 was nearly 750,000 (Agence Nationale de la Statistique et de la Démographie (ANSD), 2018), and many buyers in markets come from other parts of Senegal and neighboring countries. Diaobé is the largest grain market in the southern Senegal/Guinea-Bissau/Guinea region, attracting vendors from all three countries. Three other locations are large enough to have a daily market (Kolda, Diaobé, and Vélingara). In these markets we rented a small shop for four days each in which to conduct the auctions and minimize gawkers surrounding auction activities.

Enumerator activity followed the markets' schedule, usually from early morning to mid-afternoon. In all seven markets, enumerators approached every trader they could locate and every third woman in the market to invite them to participate in the auctions. We only targeted women

[8] At the auction design stage, we planned to sample millers and small processors (e.g. roadside food stands selling cooked maize) as we thought they were important in the maize value chain. However, these agents work with too small maize quantities to be commercially important in the value chain, thus we excluded these observations from our analysis.

as maize consumers, because our local collaborators confirmed that women are the primary food purchasers in Senegalese households, as described in other auctions conducted in Senegal (Demont, et al., 2013). Enumerators purposefully spread out throughout each market to identify and invite all traders in a market as well as a geographically-distributed sample of consumers. For example, some enumerators started to invite possible participants at one edge of the market, while others walked for 10-15 minutes toward the inside of the market before inviting people, and others were driven to other sides of the market to start the same processes. We did not systematically track refusals to participate; anecdotally, enumerators only reported two such cases in total. The shops in which we conducted the auction were very near markets, and two drivers were at the disposition of invited participants to drive them to the shop if needed. This minimized the time they were away from their market activities.

Auction structure

We purchased all the maize used in the auctions (about 1 metric ton) from one large-scale farmer near Pakour, within the Kolda region. Since WTP for maize reflects the sum of attributes perceived by the buyer, sourcing maize from a single producer helped ensure homogeneity in maize variety and quality attributes (other than MC) (Lusk and Shogren, 2007). The maize that we purchased was wet and came straight from the field, so we sun-dried it ourselves on concrete surfaces to achieve precisely the targeted moisture levels. The MC of each maize-grade was re-verified with a moisture meter every morning to ensure it had not acquired additional moisture overnight in the humid climate. We chose three moisture levels for auctioned maize: low MC was 13 percent or below, medium MC was 14 percent to 16 percent, and high MC was 17 to 19 percent. Low MC is safe for long-term storage (for example, until the next harvest), while medium and high MC levels are not, because fungi can spread at these higher levels. We preserved a one percentage point gap between each level to create clearly-distinct MC levels.

The timing of the auction within southern Senegal's maize seasonal calendar was critical to the auction's success. At the beginning of the study, freshly harvested maize from the 2015 harvest had not yet appeared in markets. The one-year old maize being sold at the time consistently measured around 14% moisture content, after approximately 12 months of storage. As our 3-week study progressed, we noticed an increasing number of producers bringing freshly harvested maize to markets. Thus, our auction coincided with the harvest season, when auction participants expect some variation in the MC of marketed maize.

In the auctions, we used two practice rounds with chocolate and pens before eliciting maize values, to help participants understand three key concepts:

1) Strategic behavior was not to their advantage, i.e. they should bid their true value for each grade of maize (Plott and Zeiler, 2005);
2) They would bid for each of the 6 grades of maize, but only one grade would be randomly selected for sale to avoid diminishing marginal returns on subsequent maize bids (Corrigan and Rousu, 2006); and
3) Their bid would be compared to all other bids that day (for traders) or to a randomly determined amount (for consumers) to determine if they had the 'high' offer for the randomly selected maize-grade.

Traders were accustomed to working with 50 kg sacks, so their bids were made throughout the day for an entire 50 kg sack and placed in envelopes. At the end of each day, the 50 kg sack that was randomly selected for sale was sold to the highest bidder of that maize-grade at the second-highest bid price (Vickrey, 1961). We chose this rolling sealed-bid approach, as opposed to organizing a group auction in one location, for traders who had limited time to leave their shops to inspect and bid on the maize.

For consumers' auctions we used the BDM mechanism and bags of 1 kg of maize, because consumers typically purchase maize in small quantities.[9] If consumers' bid for the randomly selected maize-grade was greater than or equal to an amount selected at random by the participant from an opaque bag, they "won" the auction and purchased that maize-grade at the randomly selected amount (Becker, et al., 1964). Participants were told the thirteen possible amounts in the opaque bag were uniformly distributed between 25 CFA and 325 CFA, in increments of 25 CFA. In October 2015, the prevailing maize price in Diaobé and Vélingara was 175 CFA, thus we chose 6 amounts above and below 175 CFA for the random distribution to ensure participants had a real chance of winning or losing their respective BDM auction (Lusk and Shogren, 2007).[10] Although they only bid on small quantities, we believe consumers had a real interest in the auction, as 30 percent came from families that produced maize in 2015 and 61 percent were already planning to purchase maize in the market that day.

After collecting background information about the participant and completing practice rounds with him or her, the enumerator walked the participant to an open, unlabeled maize bag (of either high, medium, or low MC). The enumerator allowed the participant to touch and inspect the maize, then asked his or her bid, or WTP for either 1 or 50 kg of maize from that bag. Unlabeled maize-grades were presented to each participant first, in a randomly varied order (Morawetz, et al., 2011). After showing participants all three unlabeled maize-grades and collecting their bids, enumerators showed participants a moisture meter and explained its

[9] It would have been logistically impossible (although theoretically sound) to procure and dry the necessary amount of maize to use the BDM mechanism with traders.
[10] The average maize price was ~$0.30/kg and the increments were ~$0.04 each (US$1≈CFA580 at the time of the auctions).

purpose. Given time constraints, enumerators did not test maize samples in front of participants, but simply explained that the meter could give a numerical reading of maize moisture. The enumerator then walked the participant over to a randomly selected labeled maize-grade (again of either high, medium, or low MC), showed them the corresponding label, explained the label's meaning, and collected their bids for each labeled maize-grade. As 64 percent of participants did not complete elementary school and only five percent knew what a moisture meter was, explaining the label's content and its meaning (low, medium, or high moisture) was necessary in the local context.[11]

It is possible that not testing maize MC in front of bidders before they placed their bids on labeled maize could introduce a bias in their bids. For instance, if participants did not trust the labeling, then bids on the labeled maize may be lower than the true value placed on maize with actual certainty about the moisture content. Our results, in particular the lower average WTP for labeled medium-MC and high-MC maize, suggest that participants did trust our labeling. It is also possible that the presentation of the moisture meter and the labeling itself could make moisture content salient and may frame the decision or imply expert opinion in a way that encourages participants to place a higher value on drier maize. The result that participants value unlabeled drier maize more than unlabeled wetter maize, and the fact that they bid on unlabeled maize before being shown the moisture meter and label, however, suggest that they had a preference for drier maize before our emphasis on maize MC.

Each participant was paid 1,500 CFA for his/her participation. This was the equivalent of 1.5-2.5 hours of work at the local living wage for unskilled workers (WageIndicator.org, 2017).

[11] We did not tell the participants anything about the food safety issues associated with wet maize prior to their bids, but recommended anyone who won auctions for medium and high MC maize to dry it before storage.

After the practice rounds, participants had on average 1,417 CFA remaining prior to entering the maize bidding rounds.

Empirical Model

Our data consist of WTP bids for six different types of maize, based on MC and labeling, from each of our 348 auction participants. This creates a balanced panel data set of 2,088 observations. We analyze these data using the following model:

$$WTP_{ij} = \beta_0 + \beta_1 MEDIUM_{ij} + \beta_2 HIGH_{ij} + \alpha L_{ij} + \gamma_1 L_{ij} * XMEDIUM_{ij} + \gamma_2 L_{ij} * XHIGH_{ij} + c_i + \varepsilon_{ij} \quad (1)$$

where the dependent variable is the WTP of participant i for maize-grade j (unlabeled low, unlabeled medium, unlabeled high, labeled low, labeled medium, or labeled high) in CFA/kg;[12] MEDIUM is a binary variable equal to one if the maize had a medium MC (14-16%) and zero otherwise; HIGH is a binary variable equal to one if the maize had a high MC (17-19%) and zero otherwise; L is a binary variable equal to one if the maize was labeled with its MC level and zero if it was unlabeled; c denotes participant fixed effects; and ε is the error term. Auction participant characteristics are not explicitly included in the regression since they are absorbed into the fixed effects. Unlabeled low-MC maize (<13%) is the omitted type in all specifications. Standard errors are clustered at the participant level in all regressions.

Table 1 describes the interpretation of the regression coefficients, which are key to understanding the empirical test of our research questions. Answering our four research questions requires testing combinations of these coefficients, for example testing whether the

[12] USD1~CFA580 at the time of the auctions.

sum of several coefficients is equal to the sum of other coefficients. In the tables and in the results section, we discuss the statistical significance of these tests.

[Insert Table 1 here]

To compare traders' and consumers' WTP, we modify Equation (1) by multiplying each term by each participant type. $CONSUMER$ is a binary variable equal to one if the respective bid came from a consumer and zero otherwise, and $TRADER$ is a binary variable equal to one if the respective bid came from a trader and zero otherwise:

$$\begin{aligned} WTP_{ij} = {} & CONSUMER * [\beta_0 + \beta_1 MEDIUM_{ij} + \beta_2 HIGH_{ij} + \alpha L_{ij} + \gamma_1 L_{ij} * MEDIUM_{ij} \\ & + \gamma_2 L_{ij} * HIGH_{ij}] + TRADER * [\beta_0 + \beta_1 MEDIUM_{ij} + \beta_2 HIGH_{ij} + \alpha L_{ij} \\ & + \gamma_1 L_{ij} * MEDIUM_{ij} + \gamma_2 L_{ij} * HIGH_{ij}] + a_i + \mu_{ij} \end{aligned} \quad (2)$$

All other variables are the same in equation (2) as in equation (1), except that a denotes participant fixed effects; and μ is the error term.

Results and Discussion

Description of participants

Table 2 provides descriptive statistics on auction participants, disaggregated by consumers and traders. As noted above, we only targeted female consumers as they are the primary food purchasers for the household, while only seven percent of traders were women. Most auction participants had started but not completed elementary school. Participants store maize post-harvest or purchase for 8-9 weeks, on average, before consuming or re-selling, thus underlining the importance of dry maize for the participants' food safety. Participants had extensive experience with maize production, drying, and storage; consumers lived in households in which the head had an average of 17 years of farming experience, and traders had 11 years of maize trading experience on average. The mean amount of maize traded was 13,344 kg annually, but our auctions included some relatively large-scale traders who skewed this value; the median was 3,000 kg and values ranged between 80 and 216,000 kg.

[Insert Table 2 here]

Unconditional average willingness to pay

Table 3 shows the unconditional mean WTP for all maize-grades. It provides preliminary insights into our research questions, and shows three key results. First, participants seem to value drier maize, as mean WTP decreases in MC across all maize-grades and participant types, a result that will be confirmed in our regression analyses. On average, WTP decreases from 145-153 CFA/kg for dry maize to 114-128 CFA/kg for the wettest maize (the two numbers refer to labeled and unlabeled maize; at this point we only aim to show general trends, and we discuss differences between labeled and unlabeled maize in more detail below). In addition, low-MC bids are higher for labeled than unlabeled maize (153 CFA/kg and 145 CFA/kg), but medium-MC and high-MC bids are *lower* for labeled than unlabeled maize (129 CFA/kg and 134 CFA/kg for medium-MC maize, and 114 CFA/kg and 128 CFA/kg for high-MC maize). This concurs with participants valuing drier maize and indicates that they trusted the labeling.

Second, MC is observable to some degree, as evidenced by the fact that WTP for unlabeled maize decreases in MC (from 145 CFA/kg for low-MC samples to 128 CFA/kg for high-MC samples). Yet, participants are not fully confident in their own ability to detect MC based on traditional methods since the magnitude of the change in WTP is lower for unlabeled maize than it is for labeled maize: WTP is lower by 17 CFA/kg for high-MC unlabeled maize than low-MC unlabeled maize, but by 39 CFA/kg for the labeled maize equivalent.

Finally, traders' WTP for unlabeled low-MC maize is 30 percent below that of consumers' on average, consistent with their need to generate a profit when reselling maize to consumers.

[Insert Table 3 here]

Regression results

Table 4 presents our main regression results, which confirm the univariate results presented above. We use the results presented in Table 4 to answer our four research questions in turn.

[Insert Table 4 here]

<u>1) Do buyers value drier maize?</u> To determine whether buyers value drier maize, we compare WTP for maize of the three grades when bidders know grain moisture content. Building upon regression coefficients from Equation 1, we perform a Chi-square test that WTP is identical for labeled maize of low, medium, and high MC. Results indicate that WTP is not equal across the three MC levels for all participants, for consumers only, and for traders only ($p<0.001$ for all three groups; Table 5). Since labeled WTP is not equal across the various MC levels, and WTP is decreasing in MC, it suggests that both consumers and traders value drier maize.

[Insert Table 5 here]

2) Do higher bids for drier maize reveal a quality premium? The higher value buyers place on drier maize includes premiums for both higher density and higher quality, as detailed above. The density difference between low- and high-MC maize is 10.5 percent; in other words, a given volume of low-MC maize contains 10.5 percent more mass than the same volume of high-MC maize (Appendix A). To measure whether bidders place a quality premium on drier maize, we test whether the difference in estimated WTP between labeled low-MC and high-MC maize is less than or equal to the density premium of maize between these MCs (10.5 percent). Results are presented in Table 5. F tests using estimated regression coefficients for all participants, and for consumer and traders separately, reject the null hypothesis that the expression is equal to zero (two-tailed p-values<0.001 for all three groups). Further, calculations of the appropriate one-tailed p-values from F tests reject the null hypothesis that the WTP difference in labeled maize is less than the density premium for all participants, and for traders and consumers separately (p<0.001 for all three tests). This is evidence that both consumers and traders are willing to pay for the higher quality of dry maize beyond the value of the additional kernels that they receive in the same mass of drier versus wetter maize on which they bid (1 kg for consumers, 50 kg for traders).

In addition to evidence of a quality premium between low-MC maize and high-MC maize, our results also show that bidders place a quality premium between each MC level. The density premium between medium- and high- MC maize is 5.9 percent. An F test shows that bidders as a whole are willing to pay a quality premium for medium-MC maize versus high-MC maize larger than the density premium ($F = 46.49$, two-tailed $p < 0.001$; one-tailed $p < 0.001$; Table 5).

Finally, we see an even more pronounced difference between labeled maize at low and medium MC, for which the density premium is 4.3 percent (Appendix A). An F test shows that the difference in WTP from low-MC to medium-MC maize is larger than the density premium for all participants ($F = 106.53$, two-tailed $p < 0.001$, one-tailed $p < 0.001$; Table 5).

The quality premium for labeled maize at the three MC levels is illustrated in Figure 1. The WTP for all participants for labeled high-MC maize is 114 CFA/kg, compared to 129 CFA/kg for labeled maize of medium MC. Of the 15 CFA difference, the value of the density premium is 7 CFA, and the average premium paid by bidders to purchase lower MC maize is 8 CFA. Between low-MC and high-MC maize, the density premium is 6 CFA and the quality premium is 18 CFA (making up the 24 CFA difference between average WTP for labeled low-MC maize and labeled medium-MC maize).

[Insert Figure 1 here]

In contrast to the quality premium paid on labeled maize, we find a much smaller or non-existent quality premium when comparing WTP for unlabeled maize of various MC (Figure 2). The test of the difference in WTP between unlabeled medium- and high-MC maize ($1.059 \cdot \widehat{\beta_2} + 0.059 \cdot 145 - \widehat{\beta_1} \geq 0$) is not significant (F value that the left-hand side expression is equal to zero = 8.69, $p = 0.003$; one-tailed $p = 0.997$). However, we see a very small (4 CFA/kg) but statistically significant quality premium when comparing WTP for unlabeled maize of low and medium MC. The value of the F test that $1.043 \cdot \widehat{\beta_1} + 0.043 \cdot 145 \geq 0$ for all participants is 19.80 ($p < 0.001$).

[Insert Figure 2 here]

Examining the distribution of participants' bids reveals that 75 percent of consumers and 80 percent of traders place a positive quality premium on labeled low-MC maize compared to labeled medium-MC maize (Figure 3). Most consumers (66 percent) have a quality premium between 1 and 100 CFA/kg. Traders' quality premiums are less varied than consumers', with 70 percent of traders' quality premiums falling between 0 and 50 CFA/kg.

These findings are consistent with responses to the complementary auction survey questions, in which 95 percent of traders said they charge more for dry maize and 96 percent of consumers stated dry maize is better. Traders reported being willing to pay more for dry maize because it weighs less (64 percent), it is safer for human consumption (37 percent), and/or consumers prefer drier maize (55 percent). Interestingly, consumers' reasons for preferring drier maize include maize having lower insect damage (77 percent), being healthier (37 percent), having a better color (33 percent), and/or being easier to process (33 percent). Only 15 percent of consumers associated drier maize with less mold and only one percent said it stores better.

[Insert Figure 3 here]

We examine next the possible heterogeneity in WTP along five key dimensions (Table 6), and the distribution of the difference between WTP for high- and low-MC maize to verify that the results are not driven by the bids of a few outliers (Figure 4). We find suggestive evidence that storage time may drive WTP, but that other key characteristics of bidders do not influence their WTP. For each additional intended week of storage, participants bid slightly more for labeled low-MC maize (0.43 CFA per kg; $p = 0.071$) than for unlabeled low-MC maize, and slightly less for labeled medium-MC maize (-0.64 CFA per kg; $p = 0.067$) than for unlabeled low-MC maize. This is likely because maize dryness becomes more important the longer one intends to store it. The statistical significance and size of the coefficients, however, imply that this result is only suggestive and very small in magnitude. WTPs at different MC levels do not differ by other characteristics of the bidders (age, education, experience growing or selling maize) or typical behavior (whether they have a habit of improving maize by drying). The lack of statistically significant variation in WTP by bidder's experience growing or selling maize is a particularly interesting finding, as extension documents often note that experienced farmers and traders can determine maize moisture content better than those with less experience; our results differ.

Figure 4 presents the distribution of WTP bids. The figure indicates that only about 10% of participants had no differences in their bids between high and low MC maize, regardless of labeling. This implies that our findings are not driven by large outliers among participant bids, but that the large majority of participants exhibited a preference in moisture content. The distributions are roughly normal for unlabeled and labeled maize. However, unlabeled maize is centered around zero, whereas labeled maize is centered around 25 CFA/ kg. This means that for labeled maize, participants bid higher for low than high MC maize.

3) Can participants determine MC on their own, and are they confident in their ability?

Regression results show that buyers have significantly lower WTP for wetter maize, even when MC is not labeled. Participants have different WTP for wetter unlabeled maize than for drier unlabeled maize ($\chi^2 = 51.66$, 33.15, and 20.45 for all participants, consumers, and traders;

p < 0.001 in all three groups; Table 5). The result indicates that both types of buyers have some ability to discern maize MC using traditional methods.

It is worth noting that since labeled wetter maize is more deeply discounted than unlabeled maize of the same MC, one might question whether buyers feel confident they can identify drier maize in the market, which is unlabeled. We test this hypothesis by comparing the slopes for maize of low and high MC between unlabeled and labeled maize-grades. Table 4 shows that we reject the hypothesis that $\widehat{\gamma_2} = 0$ at the 99 percent confidence level, indicating that auction participants could not detect maize MC using local methods with certainty ($\widehat{\gamma_2}$ = -22,-28,-15; p < 0.001 for all participants, traders and consumers, respectively). This evidence is consistent with the finding that bidders place a quality premium on drier maize. It suggests that the quality premium reflects at least in part the certainty arising from labeling. Participants trust that the maize sample they are bidding on is dry and safe for storage.

4) Do traders and consumers differ in their ability to detect maize MC? Since both traders and consumers value drier maize and can discern maize MC to some extent without labeling, we turn to testing whether the ability to discern maize MC differs for traders and consumers. Such a difference could indicate asymmetric information between the two parties.[13]

The primary statistical test consists of comparing the unlabeled WTP slopes for maize of low and high MC between traders and consumers, which simplifies to $\widehat{\beta_{2\,C}} = \widehat{\beta_{2\,T}}$ (full test detailed in Table 5). The low Chi-square value of the test (χ^2 = 0.31; p = 0.579) indicates that the

[13] Our auctions estimate consumers' and trader's WTP to *acquire* maize, but information asymmetries would impact transactions in which one party buys and the other sells (either consumers selling their own production to traders, or traders selling maize to consumers who have run out of their own stock). Yet, both consumers' and traders' differential ability to tell maize MC without a label or moisture meter in a purchasing situation would likely extend to a similar ability when both act as sellers, and could therefore reveal potential information asymmetry.

difference in WTP for unlabeled maize of low and high MC is not statistically significantly different for traders and consumers. The result is similar when comparing low and medium MC, as $\widehat{\beta_{1\,C}} = \widehat{\beta_{1\,T}}$ (χ^2 = 1.67; p = 0.198; Table 5). In short, we do not find evidence of a differential ability to detect maize MC level between traders and consumers.

Study Limitations

The study suffers from two main limitations. First, the quality premium could reveal a temporary preference for drier maize rather than a permanent valuation. For example, Hoffmann, et al. (2015), find an increased demand for maize labeled as aflatoxin-free in Kenya after an intensive price discount/food safety campaign, but the level of demand reduced from its peak within one month, leading the authors to question the sustainability of the behavior change. Given that we provided no information about the improved safety and storability of drier maize, that we elicited homegrown WTP for maize moisture content, and that auction participants overwhelmingly stated they preferred drier maize in a pre-auction survey, we do not think the quality premium documented here was a temporary preference for drier maize.

Second, previous experiments have found WTP for individual attributes diminishing in the number of attributes presented to buyers (Gao and Schroeder, 2009). By presenting only one labeled attribute to buyers (moisture content) in our action, we have assumed that MC is independent of all other attributes not provided. While this is admittedly unlikely, it is important to note that we procured all maize used in our auction from one large-scale farmer in the area and conducted our auction using freshly harvested maize, other attributes besides moisture content should be relatively constant across our sample.

Conclusion

Quickly drying grains to a low, safe moisture content is key to increasing their storability and limiting the spread of aflatoxins, potent carcinogenic toxins for children, adults, and livestock. We conducted experimental auctions in southern Senegal, in which consumers and traders bid on labeled and unlabeled maize of varying MC. In doing so we attempt to answer four main questions that have received only limited attention in the literature do date: (1) Do consumers and traders *value* drier maize? (2) If they value drier maize, does the higher value constitute a quality premium? (3) Are traders and consumers confident in their ability to determine the MC of maize on their own using traditional methods? (4) Do traders and consumers differ in their ability to detect maize MC using traditional methods?

We find that auction participants are willing to pay statistically significantly more for labeled maize with lower MC (Question 1), and the higher WTP more than makes up for the larger number of kernels in drier maize, and constitutes a quality premium (Question 2). We also find that buyers have a limited ability to determine moisture content on their own and can thus seek out dry maize in the market, but benefit from the certainty that a reliable moisture content label provides (Question 3).

Finally, we find no evidence that traders and consumers differ in their ability to detect maize MC (Question 4). Whether this result indicates the absence of information asymmetry between traders and consumer depends in part on whether traders resell maize to consumer or to other traders/wholesalers. Our data indicate that 86 percent of traders intended to resell (at least some of) the maize they bid on during our auction, but we do not know who they intended to resell to. If they intended to resell to consumers, the result could be due to traders not being willing to pay a higher price for drier unlabeled maize because they intend to resell it to consumers, who they may know cannot tell maize MC reliably. If they intended to resell to other traders or wholesalers, who could be more likely to use moisture meters, the finding could be a sign of absence of information asymmetries between traders and consumers. Our data do not allow us to disentangle these two possible explanations, which remains an interesting question for future research.

Taken together, the results point to four implications. First, maize buyers care about the dryness of the maize that they purchase. Drier maize can be stored longer and more safely. The low level of awareness of health safety concerns with wet maize, primarily aflatoxins contamination (Hell, et al., 2000, James, et al., 2007, Prieto, et al., 2017), suggests that buyers are motivated primarily by the storage benefits of drier maize (less mold/ kernel discoloration/ wastage).

Second, our finding that buyers are willing to pay a specific and large quality premium for drier maize that has the MC labelled on the bag indicates that there is demand for such higher-quality maize (as measured by moisture content level). On average, participants in our auctions were willing to pay 39 CFA per kg more for labeled low-MC maize than for labeled high-MC maize, equivalent to 22 percent of the local market price at the time of the auction.

Third, the existing demand for drier maize, and the fact that maize moisture content cannot be reliably detected by individuals using traditional methods, provide a unique opportunity for policy efforts to improve food safety and reduce aflatoxins by promoting reliable and cheap methods to reveal maize moisture content. One such method is the sale of maize by both weight and volume, which together reveal maize moisture content. Widely known benchmark weight and volume for various crops would allow buyers and sellers of these crops to instantly know whether the grains are safe or unsafe for storage (in the case of maize, safe for storage means at 13 percent moisture content or lower). For example, one kg of sufficiently-dry maize fills a certain standardized measure of volume, and any overflow indicates that the maize is too wet for storage and provides conditions for the growth of aflatoxins. This would entail promoting the use of a simple volume measure, such as a standardized plastic bucket, in places where maize is currently traded on weight alone.[14] In places where maize is currently traded on volume alone, accurate, standardized, and monitored scales would need to be used. One limitation of this approach is that various crops, and varieties of the same crop, differ in density by moisture content. This could require the use of either various containers, or one container marked with fill lines for various crop and varieties. Such containers would need to be regulated, and liquidity and knowledge constraints would likely limit their adoption.

Another option to accurately test MC level is to disseminate low-cost moisture meters that are within a smallholder household's budget constraints. The low cost of these devices would also help assuage fears that one party in a transaction may alter the moisture reading from their meter, if both parties can bring their own device. A simple calculation of the cost and benefits of adopting an existing low-cost moisture meter suggests that the economics are favorable. Tubbs, et al. (2017) report how a US$1.13 hygrometer (wholesale price in the US after importing from China) is a reliable maize moisture detection device. We estimate that it could be profitably sold for about US2.50 in the local market where we conducted our auction. Because of the volume of maize they transact, traders are the most likely to benefit from this

[14] Our study does not provide data on this point, but we speculate that at least three factors play an important role in preventing the adoption of transactions by weight and volume. First, awareness of aflatoxins and food safety is limited (Hell, et al., 2000, James, et al., 2007, Prieto, et al., 2017), so that many market actors may not strongly perceive the need to improve upon existing transaction standards. Second, some actors in crop markets have incentives against the use of standard measurement in transactions (Bernard et al. 2017). Third, unlike cash crops with clear sales channels and likely higher gains from standardization and labeling, market gains from establishing moisture content in maize, a mostly auto-consumed staple crop, are more distributed and each actor on his/her own has a lower incentive to introduce new transaction standards.

innovation. Given traders' mean WTP for certainty about moisture content (based on the difference in WTP for labeled low-MC and unlabeled medium-MC maize) of about 2.1 US cents (12 FCFA), traders would need to sell about 114 kg of maize to break even for a US$2.50 purchase price. In our data, they reported selling 13,300 kg annual on average. Constraints to the adoption of such devices include availability and liquidity constraints; their study represents an interesting avenue for further research.

Fourth, maize moisture content being a largely, but not entirely, unobservable attribute is an important insight. It implies that a buyer's homegrown knowledge about moisture content, and whether that knowledge is sufficient for contracting purposes, should be carefully measured and considered when evaluating the demand for and barriers to the production of such goods. In the case of maize, our result suggests that independent verification of maize MC levels could allow for more formal contracting between buyers and sellers for maize MC levels. In complement, branding of crops by origin, farmer, farmer cooperative, or trader could also increase the incentive of producers and intermediaries to dry their products to safe levels. In a related context, Hoffmann and Moser (2017) showed that the aflatoxins content of various maize flour brands in Kenya was strongly negatively related to their price, suggesting that establishing one's reputation as a safe producer or trader could partially substitute for formal labeling, particularly when considering maize purchases (e.g. between farmer and trader or between consumer and trader) as repeated transactions over time.

Taken together, our results show that post-harvest processes play an important role in enhancing the functioning of food markets and public health in developing countries. Improving post-harvest practices has received less attention from researchers and policymakers than other issues in agricultural production and processing until now, but simple intervention and policies have the potential to leverage existing demand and significantly improve the health and well-being of smallholder farmers in developing countries.

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Table 1. Interpretation of regression coefficients

$\hat{\beta}_1$	Marginal WTP of unlabeled medium MC maize compared to unlabeled low MC maize
$\hat{\beta}_2$	Marginal WTP of unlabeled high MC maize compared to unlabeled low MC maize
$\hat{\alpha}$	Marginal WTP of labeled low MC maize compared to unlabeled low MC maize
$\hat{\gamma}_1$	Marginal WTP for labeled medium MC maize compared to $\hat{\alpha}$ and $\hat{\beta}_1$
$\hat{\gamma}_2$	Marginal WTP for labeled high MC maize compared to $\hat{\alpha}$ and $\hat{\beta}_2$
$\widehat{\beta_1} + \hat{\alpha} + \widehat{\gamma_1}$	Marginal WTP of labeled medium MC maize compared to unlabeled low MC maize. This is equivalent to the interpretation of $\hat{\beta}_1$, $\hat{\beta}_2$, and $\hat{\alpha}$. We use the delta method to calculate the variance (Greene, 2012).
$\widehat{\beta_2} + \hat{\alpha} + \widehat{\gamma_2}$	Marginal WTP of labeled high MC maize compared to unlabeled low MC maize. This is equivalent to the interpretation of $\hat{\beta}_1$, $\hat{\beta}_2$, and $\hat{\alpha}$. We use the delta method to calculate the variance (Greene, 2012).

Table 2. Descriptive statistics of auction participants

	Consumers (n=182)	Traders (n=166)
Female (%)	100	7
Mean age (years)	35	40
Completed elementary school (%)	41	35
Mean storage time post-harvest or purchase, before consuming or re-selling (weeks)	9	8
Mean years growing (consumers) or trading (traders) maize	17	11
Mean annual kg stored (consumers) or sold (traders)	304	13,344

Table 3. Mean WTP by moisture content and participant type (CFA/kg)

	Low – safe		Medium – unsafe		High – unsafe	
	Unlabeled	Labeled	Unlabeled	Labeled	Unlabeled	Labeled
Traders	119	125	112	106	104	94
Consumers	169	178	155	149	151	133
All Participants	145	153	134	129	128	114

"Safe" denotes maize is safe for long-term storage. USD1≈FCFA580 at the time of the auction (October 2015).

Table 4. Regression results - Experimentally varied parameters

Equation:	(1)	(2)	
Coefficients Interacted With:	N/A	$P_{Consumer}$	P_{Trader}
Panel A. Regression coefficients			
Unlabeled medium ($\widehat{\beta_1}$)	-10 ***	-13 ***	-7 ***
	(2.20)	(3.72)	(2.10)
Unlabeled high ($\widehat{\beta_2}$)	-17 ***	-18 ***	-15 ***
	(2.52)	(4.38)	(2.20)
Labeled low ($\hat{\alpha}$)	8 ***	10 **	-6 ***
	(2.22)	(3.99)	(1.60)
Labeled * Medium ($\widehat{\gamma_1}$)	-14 ***	-16 ***	-11 ***
	(2.82)	(5.03)	(2.10)
Labeled * High ($\widehat{\gamma_2}$)	-22 ***	-28 ***	-15 ***
	(2.99)	(5.24)	(2.43)
Number of observations		2,088	
Number of unique bidders		348	
Panel B. Change in WTP between unlabeled low-MC maize and:			
Labeled medium ($\widehat{\beta_1} + \hat{\alpha} + \widehat{\gamma_1}$)	-16 ***	-19 ***	-13 ***
	(2.19)	(3.61)	(2.31)
Labeled high ($\widehat{\beta_2} + \hat{\alpha} + \widehat{\gamma_2}$)	-31 ***	-36 ***	-25 ***
	(2.69)	(4.53)	(2.60)

Coefficients and sums of coefficients are in FCFA (USD1~FCFA580 at the time of the auctions). Regressions include participant fixed effects. Standard errors clustered at the auction participant level in parentheses. *** p<0.01, ** p<0.05, * p<0.10. In Panel B, we use the delta method to calculate the variance of the coefficients (Greene, 2012).

Table 5. Hypotheses tests based on regression coefficients.

Research question	Hypothesis test	Coefficients in Table 4	Simplifies to	Sample	Test result (F or χ^2)
(1)	Is WTP identical for labeled maize of low, medium, and high MC?	$(\widehat{\beta_0} + \hat{\alpha}) =$ $(\widehat{\beta_0} + \widehat{\beta_1} + \hat{\alpha} + \widehat{\gamma_1}) =$ $(\widehat{\beta_0} + \widehat{\beta_2} + \hat{\alpha} + \widehat{\gamma_2})$	$(\widehat{\beta_1} + \widehat{\gamma_1}) =$ $(\widehat{\beta_2} + \widehat{\gamma_2}) = 0$	All participants	278.8***
				Consumers only	207.8***
				Traders only	83.7***
(2)	Is the difference in estimated WTP between labeled *low-MC and high-MC* maize ≤ the density premium (10.5%)?	$(\widehat{\beta_0} + \hat{\alpha}) -$ $(\widehat{\beta_0} + \widehat{\beta_2} + \hat{\alpha} + \widehat{\gamma_2}) \leq$ $(\widehat{\beta_0} + \widehat{\beta_2} + \hat{\alpha} + \widehat{\gamma_2}) * 0.105$	$1.105 * (\widehat{\beta_2} + \widehat{\gamma_2}) +$ $0.105 * (\hat{\alpha} + \widehat{\beta_0}) \geq 0$	All participants	286.2***
				Consumers only	211.8***
				Traders only	86.8***
(2)	Is the difference in estimated WTP between labeled *medium-MC and high-MC* maize ≤ the density premium (5.9%)?	$(\widehat{\beta_0} + \widehat{\beta_1} + \hat{\alpha} + \widehat{\gamma_1}) -$ $(\widehat{\beta_0} + \widehat{\beta_2} + \hat{\alpha} + \widehat{\gamma_2}) \leq$ $(\widehat{\beta_0} + \widehat{\beta_2} + \hat{\alpha} + \widehat{\gamma_2}) * 0.059$	$1.059 * (\widehat{\beta_2} + \widehat{\gamma_2}) +$ $0.059 * (\widehat{\beta_0} + \hat{\alpha}) -$ $(\widehat{\beta_1} + \widehat{\gamma_1}) \geq 0$	All participants	106.5***
				Consumers only	31.6***
				Traders only	16.0***
(2)	Is the difference in estimated WTP between labeled *low-MC and medium-MC* maize ≤ the density premium (4.3%)?	$(\widehat{\beta_0} + \hat{\alpha}) -$ $(\widehat{\beta_0} + \widehat{\beta_1} + \hat{\alpha} + \widehat{\gamma_1}) \leq$ $(\widehat{\beta_0} + \widehat{\beta_1} + \hat{\alpha} + \widehat{\gamma_1}) * 0.043$	$1.043 \cdot (\widehat{\beta_1} + \widehat{\gamma_1}) +$ $0.043 * (\hat{\alpha} + \widehat{\beta_0}) \geq 0$	All participants	46.4***
				Consumers only	83.2***
				Traders only	29.4***
(3)	Are the unlabeled maize-grade slopes equal?	$\widehat{\beta_0} = \widehat{\beta_0} + \widehat{\beta_1} = \widehat{\beta_0} + \widehat{\beta_2}$	$\widehat{\beta_1} = \widehat{\beta_2} = 0$	All participants	51.7***
				Consumers only	33.2***
				Traders only	20.5***
(3)	Are the differences in WTP between low and high MC equal for unlabeled and labeled maize?	$\widehat{\beta_0} - (\widehat{\beta_0} + \widehat{\beta_2}) =$ $(\widehat{\beta_0} + \hat{\alpha}) - (\widehat{\beta_0} + \widehat{\beta_2} + \hat{\alpha} + \widehat{\gamma_2})$	$\widehat{\gamma_2} = 0$	All participants	*** for all. See coefficients $\widehat{\gamma_2}$ in Table 4.
				Consumers only	
				Traders only	
(4)	Do traders and consumers differ in their ability to detect maize MC between low and high levels?	$\widehat{\beta_{0\,C}} - (\widehat{\beta_{0\,C}} + \widehat{\beta_{2\,C}}) =$ $\widehat{\beta_{0\,T}} - (\widehat{\beta_{0\,T}} + \widehat{\beta_{2\,T}})$	$\widehat{\beta_{2\,C}} = \widehat{\beta_{2\,T}}$	All participants	0.31
(4)	Do traders and consumers differ in their ability to detect maize MC between low and medium levels?	$\widehat{\beta_{0\,C}} - (\widehat{\beta_{0\,C}} + \widehat{\beta_{1\,C}}) =$ $\widehat{\beta_{0\,T}} - (\widehat{\beta_{0\,T}} + \widehat{\beta_{1\,T}})$	$\widehat{\beta_{1\,C}} = \widehat{\beta_{1\,T}}$	All participants	1.67

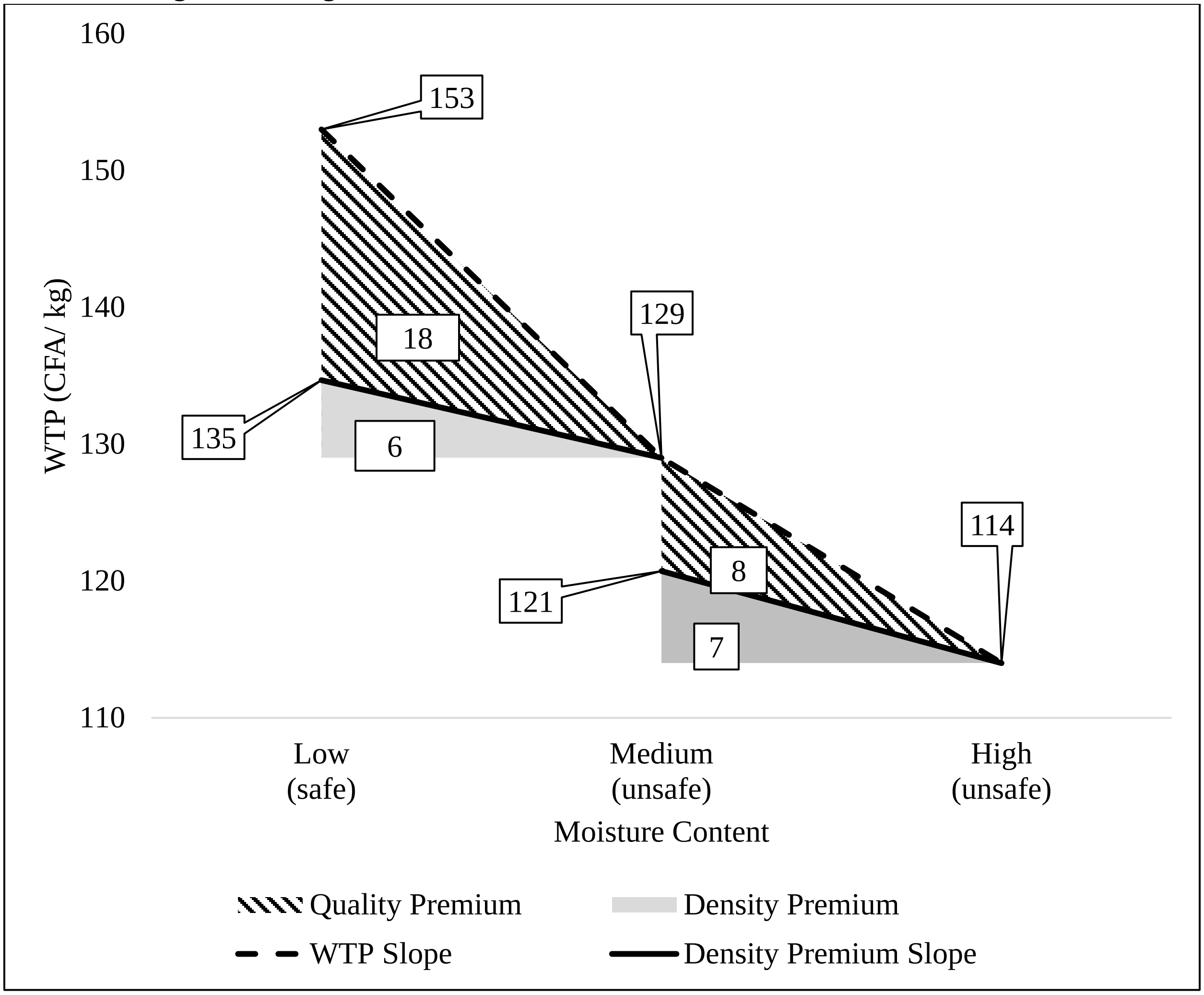
*** p<0.01, ** p<0.05, * p<0.10. In the test of research question (2) our fixed effects regression model does not estimate a coefficient $\widehat{\beta_0}$ for all participants. In the test we replace this coefficient with the unconditional sample mean for unlabeled low-MC maize (145 CFA/kg for all participants, 169 CFA/kg for consumers, and 119 CFA/kg for traders; Table 3). Both two-tail and one-tail p-values of all tests of research question (2) are significant at the 0.01 level or below.

Table 6. Heterogeneity tests of experimentally varied parameters.

	Age (years)	Participant has any formal education	Experience growing or selling maize	Storage time (weeks)	Improve maize by drying it
Unlabeled medium ($\widehat{\beta_1}$) * Interaction variable in heading	-0.09 (0.18)	3.74 (3.85)	0.11 (0.22)	0.24 (0.20)	2.60 (2.25)
Unlabeled high ($\widehat{\beta_2}$) * Interaction variable in heading	-0.23 (0.23)	7.21 (4.61)	-0.07 (0.24)	0.11 (0.20)	3.46 (2.81)
Labeled low ($\hat{\alpha}$) * Interaction variable in heading	-0.31 (0.21)	1.60 (4.29)	0.16 (0.21)	0.43* (0.24)	4.32 (3.08)
Labeled * Medium ($\widehat{\gamma_1}$) * Interaction variable in heading	0.44* (0.25)	-5.48 (5.48)	0.13 (0.29)	-0.64* (0.35)	-4.89 (3.72)
Labeled * High ($\widehat{\gamma_2}$) * Interaction variable in heading	0.26 (0.27)	-5.42 (6.21)	0.39 (0.28)	-0.32 (0.28)	-5.62 (4.19)

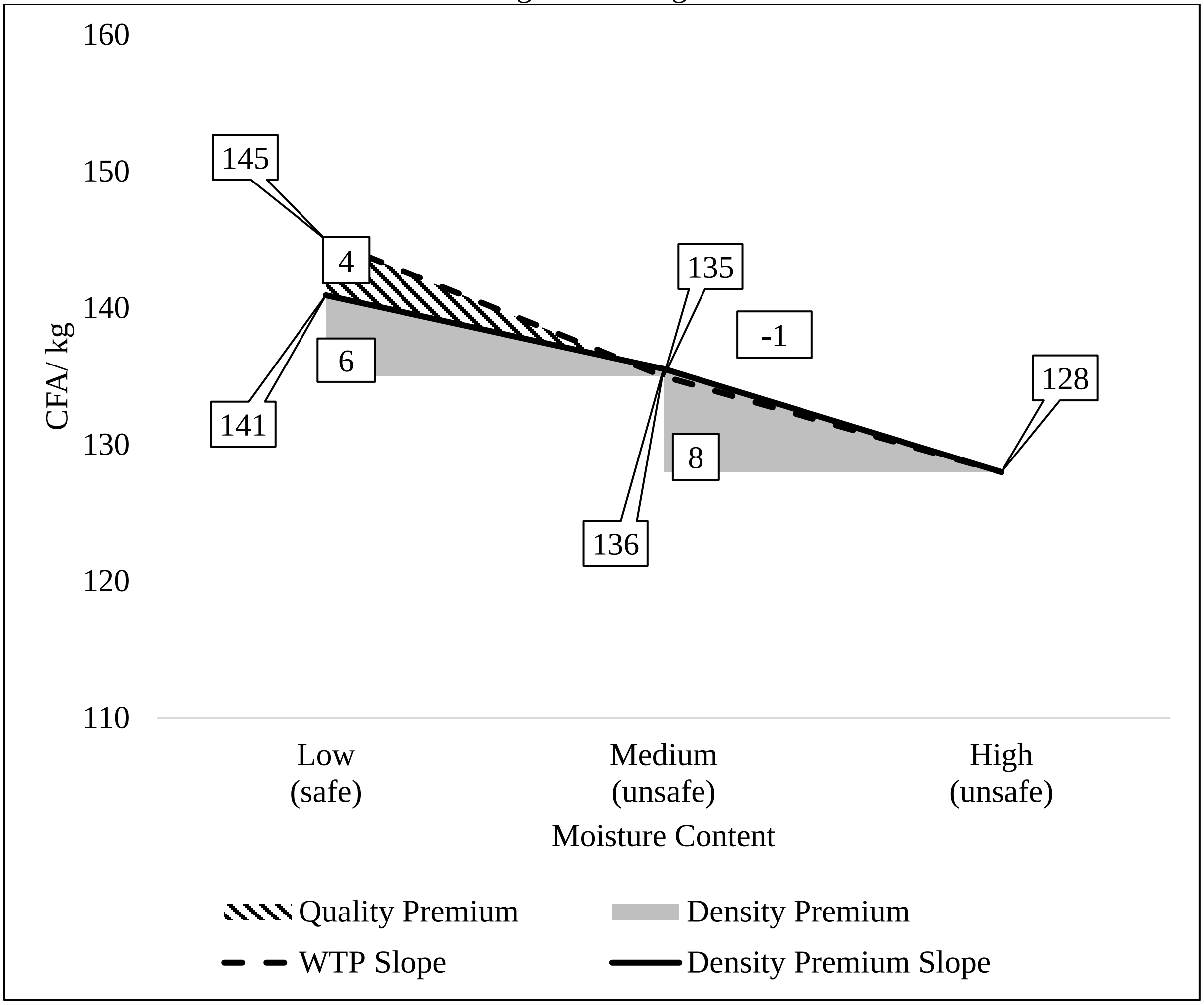
Coefficients are in FCFA (USD1~FCFA580 at the time of the auctions). Regressions use random effects models. Standard errors clustered at the auction participant level in parentheses. *** p<0.01, ** p<0.05, * p<0.10. The variable indicated in the heading and the five binary variables for maize moisture content are always included in all regressions, but not shown for clarity. The variable indicated in the heading is interacted with each experimentally varied parameter.

Figure 1. Calculated quality and density premiums for labeled maize. "Safe" denotes maize that is safe for long-term storage.



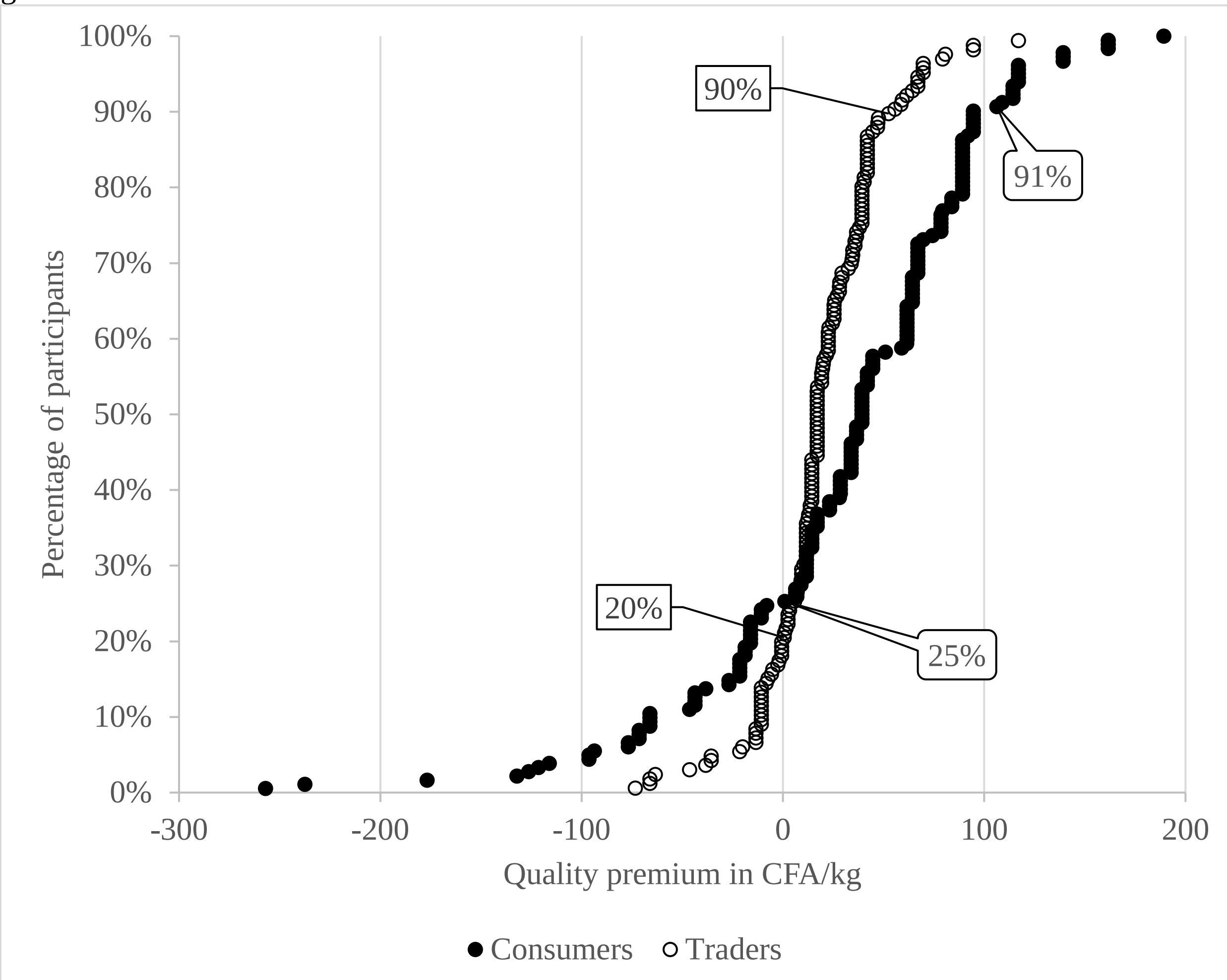
The exchange rate in October 2015 was 580 FCFA/USD.

Figure 2. Calculated quality and density premiums for <u>unlabeled</u> maize
"Safe" denotes maize that is safe for long-term storage.



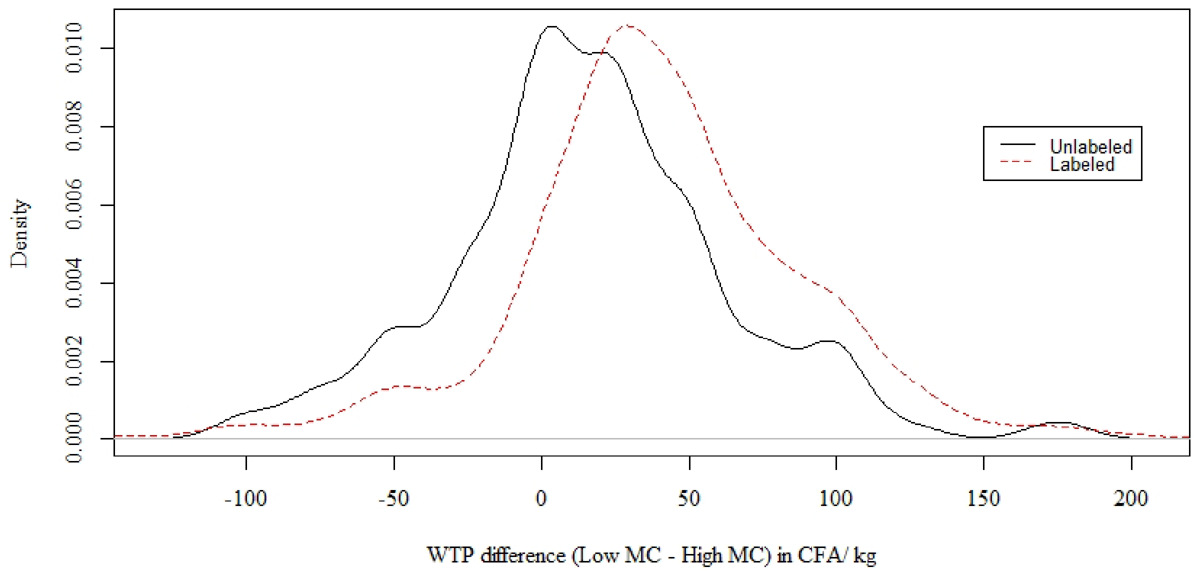
The exchange rate in October 2015 was 580 FCFA/USD.

Figure 3. Consumer and trader quality premiums for low vs. high MC maize. Negative values indicate that buyer WTP did not fully compensate for the density premium between the maize-grades.



The exchange rate in October 2015 was 580 FCFA/USD.

Figure 4. Probability density functions for the differences in WTP between low and high MC for labeled and unlabeled maize.



Online Appendix A. – Calculation of density premiums

We use the relationship density (d) = mass (m)/volume (v) to calculate how a change in maize MC would affect maize density, and thus mass and volume.

We use the standard grain bulk density equation for maize, where maize density (kg/m^3) $= 1086.3 - 2971 * MC + 4810 * MC^2$ (Brusewitz, 1975). In this equation, MC is the wet, not dry, basis MC. Wet basis MC is the type most commonly measured by moisture meters. Using the example of 19% MC maize, we calculate its density to be 695.45 kg/m^3, and 50 kg of maize (a standard bag, and the amount we asked traders to bid on) at 19% MC occupies a volume of 0.072 m^3. We then choose to keep volume constant and measure the change in weight for various moisture content levels. We choose to base the calculations on a standard bag of 50 kg, at 19% MC (Table A1); the specific mass used in the calculation does not matter because we focus on the percent change in weight for various moisture content levels.

Table A1. Change in weight of maize contained in 0.072 m^3 at varying moisture content levels.

Moisture content (MC; %)	Density (kg/m^3)	Weight (kg)
19	695.45	50.0
18 (high MC)	707.36	50.9
17	720.24	51.8
16	734.08	52.8
15 (medium MC)	748.88	53.8
14	764.64	55.0
13 (low MC)	781.36	56.2

For this article, we are interested in the differences between three MC (18%, 15%, and 13%) representative of each level (high, medium, and low). Thus, the density premium for medium MC maize as compared to high MC maize is 5.9%, the change in density (or weight) between 15 percent MC maize and 18 percent MC maize. For low MC maize as compared to medium MC maize, it is 4.4% (the change in density between 13 percent MC maize and 15 percent MC maize). For low MC maize as compared to high MC maize, it is 10.5% (the change in density between 13 percent MC maize and 18 percent MC maize). The density premium for low MC maize compared to high MC maize is slightly different from the sum of the density premiums for low-medium and medium-high MC (10.2%) because density is non-linear in moisture content (Sangamithra, et al., 2016). Figure A1 shows maize density at moisture contents ranging from 1% to 100% based on Brusewitz's formula indicated above; note that at the MC range that we tested (13% and under, to 19%), the non-linearity is very small.

Figure A1. Maize density at various moisture content levels.