African Crop Science Journal, Vol. 29, No. 4, pp. 497 - 512
Printed in Uganda.
ISSN 1021-9730/2021 $4.00

DOI: https://dx.doi.org/10.4314/acsj.v29i4.6

CONSUMER PREFERENCES FOR THE QUALITY CHARACTERISTICS OF SORGHUM GRAIN IN EASTERN UGANDA: A CHOICE EXPERIMENT APPROACH

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(*Received 26 October 2020; accepted 16 November 2021*)

ABSTRACT

Sorghum (*Sorghum bicolor*) is an important staple food crop for millions of food insecure people in the Semi-Arid Tropics. However, the crop has not been fully exploited due to undesirable consumer characteristics. The objective of this study was to identify quality characteristics that consumers of sorghum prefer so as to increase its consumption in Uganda. Quality in this study was evaluated based on four sensory characteristics of *atapa (atapa* is a local name for sorghum paste in Eastern Uganda): colour, aroma, taste and texture; and grain size. A choice experiment was conducted to analyse consumer preferences for quality characteristics of *atapa.* The discrete choices obtained from the choice experiment were analysed using Mixed Logit models fitted in preference- and willingness to pay-space. Results revealed that sweet taste, good aroma, elastic texture and big grain size had positive effects on the consumer preference. In terms of magnitude, sweet taste had the largest effect on consumer preference followed by aroma. Grain size was important because consumers believed that the bigger the size, the more the flour that would be obtained after milling. None of the colours was found to be important; instead respondents associate the existing colours of different varieties with their known texture, taste and aroma. There were also significant positive implicit prices for the preferred (non-colour) attributes, implying that consumers were willing to pay a price premium for sweet taste, good aroma, elastic texture and big grain size. The highest premium would be paid for sweet taste (US$ 0.69) followed by good aroma (US$ 0.39). We also evaluated five hypothetical varieties (1, 2, 3, 4 and 5) based on the implicit prices of the individual attributes that constitute the varieties. We found out that varieties with a good taste, good aroma, elastic texture and big grain size had larger total willingness to pay values than those missing any of these attributes. We conclude that sweet taste and aroma and elastic texture are the most important quality attributes of *atapa.* Thus, we recommend to sorghum breeders to consider these quality attributes in their breeding programmes if consumption of sorghum-based foods is to increase.

Key Words: Implicit prices, sensory characteristics, *Sorghum bicolor*, willingness to pay

RÉSUMÉ

Le sorgho (*Sorghum bicolor*) est une culture vivrière de base importante pour des millions de personnes en situation d'insécurité alimentaire dans les régions tropicales semi-arides. Cependant, la culture n'a pas été pleinement exploitée en raison de caractéristiques indésirables des consommateurs de sorgho. L'objectif de cette étude était d'identifier les caractéristiques de qualité que les consommateurs de sorgho préfèrent afin d'augmenter sa consommation en Ouganda. La qualité dans cette étude a été évaluée sur la base de quatre caractéristiques sensorielles de l'*atapa* (*atapa* est un nom local pour la pâte de sorgho dans l'Est de l'Ouganda) : la couleur, l'arôme, le goût et la texture ; et la taille des grains. Une expérience de choix a été menée pour analyser les préférences des consommateurs pour les caractéristiques de qualité de l'*atapa*. Les choix discrets obtenus à partir de l'expérience de choix ont été analysés à l'aide de modèles logit mixtes ajustés dans l'espace de préférence et de volonté de payer. Les résultats ont révélé qu'un goût sucré, un bon arôme, une texture élastique et une grosse granulométrie avaient des effets positifs sur la préférence du consommateur. En termes d'amplitude, le goût sucré a eu le plus grand effet sur les préférences des consommateurs, suivi de l'arôme. La taille des grains était importante parce que les consommateurs pensaient que plus la taille était grande, plus la farine qu'on obtiendrait après la mouture était importante. Aucune des couleurs n'a été jugée importante; au lieu de cela, les répondants associent les couleurs existantes des différentes variétés à leur texture, leur goût et leur arôme connus. Il y avait également des prix implicites positifs significatifs pour les attributs préférés (non colorés), impliquant que les consommateurs étaient prêts à payer un prix plus élevé pour un goût sucré, un bon arôme, une texture élastique et une grosse granulométrie. La prime la plus élevée serait payée pour le goût sucré (0,69 $ US) suivi d'un bon arôme (0,39 $ US). Nous avons également évalué cinq variétés hypothétiques (1, 2, 3, 4 et 5) sur la base des prix implicites des attributs individuels qui constituent les variétés. Nous avons découvert que les variétés avec un bon goût, un bon arôme, une texture élastique et une grosse taille de grain avaient des valeurs totales de consentement à payer plus élevées que celles qui ne manquaient aucun de ces attributs. Nous concluons que le goût et l'arôme sucrés et la texture élastique sont les attributs de qualité les plus importants de l'*atapa*. Ainsi, nous recommandons aux sélectionneurs de sorgho de considérer ces attributs de qualité dans leurs programmes de sélection si la consommation d'aliments à base de sorgho doit augmenter.

Mots Clés : prix implicites, caractéristiques sensorielles, *Sorghum bicolor*, consentement à payer

INTRODUCTION

Sorghum (*Sorghum bicolor*) is ranked fifth in world cereal crop production and utilisation, after wheat, rice, maize and barley (Nangoti *et al*., 2004). Sorghum is the second most important cereal (after maize) in Sub Saharan Africa (SSA) (FAO, 2011; Timu *et al*., 2014). In Uganda, it is the third most important staple cereal food crop following maize and rice (House, 1995; Kaizzi undated). Currently sorghum consumption for human food occurs in low-income countries; while high-income countries typically use sorghum as a component in livestock feed or to produce ethanol (Babatunde, 2001; FAS, 2013). For instance, in the United States over 90 percent of the sorghum consumed is used as a component in livestock feed (FAS, 2013). In Africa, human consumption of sorghum accounts for almost three-quarters of total utilisation where it remains a principal source of calories, protein, vitamins and minerals (Cavatassi *et al*., 2011; Omoba *et al.*, 2015). In Uganda, a large amount of sorghum is predominantly grown in Northern and Eastern Uganda where most of it is consumed as food (USAID, 2010). It is both a commercial and a staple food crop for over 95 percent households in Eastern Uganda (Nabimba *et al*.,

2005). In the competitive environment of multinational enterprises, sorghum has proven to be a better alternative to barley for large-scale beer brewing (FAS, 2013; Makindara *et al.*, 2013)..

Even though sorghum is better adapted to drier areas than maize, it's adoption rate by farmers has been lower than that of maize (Mafuru, *et al.*, 2007). Improved varieties of sorghum have been developed by several national and international research organisations (Timu *et al.*, 2014), but few of these varieties have been adopted (Kayode *et al.*, 2005; Langyintuo, 2008; Cavatassi *et al.*, 2011) due to their inability to meet farmers' sorghum consumption expectations.. As a result of low adoption, use of sorghum in food industry has been minimal, in spite of its greater availability, comparatively good nutritional value and low price (Rohrbach, 2003). Virtually, all production is undertaken for subsistence purposes, with less than 2 percentof each season's harvest entering the formal market (Rohrbach and Kiriwagulu, 2001; Makindara *et al.*, 2010). For the new varieties to be adopted and for the purposes of enhancing marketability of sorghum, the varieties must comprise the traits desired by the end-users (Girma *et al.*, 2017). Such characteristics/attributes like grain colour, grain size, taste are important because they have a bearing on acceptability of new products (Kimenju *et al.*, 2005). According to Vazques-Araujo *et al.* (2012), the first step in developing products attractive for consumers is understanding their needs and expectations; because it is these needs that will influence acceptability, and hence adoption of the new varieties. If the consumers are able to accept and express willingness to pay for the different traits embedded in the improved varieties, adoption is inevitable (Girma *et al.*, 2017). This study was undertaken to identify quality characteristics that consumers of sorghum prefer so as to increase its consumption in Uganda

METHODOLOGY

The study area and sample selection. The study was conducted in eastern Uganda in the districts of Soroti, Kumi and Bukedea, where per *capita* consumption of sorghum in Uganda is highest (USAID, 2010). A total of 120 households were selected from the population using random sampling procedure. One sub-county was randomly selected from each district, from which two parishes were randomly selected, and from each parish two villages were randomly selected. Ten respondents were then randomly selected from each village. The respondent was a household member who either prepared *atapa* for consumption or purchased sorghum for home consumption.

The decision to use a sample of 120 was due to the Nlogit Software limitation. Owing to huge cost of purchasing the software, we could only afford to use a leased version whose capability is limited to 1500 observations. A sample of 120 results into 1,440 observations (each respondent presented with four choice scenarios, of which each scenario had three alternatives, giving a total of 12 observations for each respondent) would enable us to have a manageable (by the software) sample while having equal representation in each block (refer to the section of Choice experiment ahead for details about blocking).

Data collection. Responses for both sections were obtained through face-to-face interviews with the respondents. A semi-structured questionnaire, which had two sections, was used to elicit information from respondents. The first part had questions related to socio-economic characteristics, consumer's knowledge about improved sorghum varieties, consumption and marketing. Data of this kind was necessary because we conceptualised that these factors influence consumer preference and willingness to pay. The second part consisted of four choice sets designed through

a choice experiment (CE). The data from the CE enabled us to evaluate the trade-offs consumers made between characteristics/ attributes and price.

Choice experiment. A choice experiment (CE) was used to investigate consumers' preferences for key sorghum attributes. Choice experiments are based on Lancaster's theory of consumer choice, which postulates that consumers choose products based on their attributes (Lancaster, 1966). CEs permit multiple attributes to be evaluated, thereby allowing the researcher to estimate trade-offs between different alternatives (Lusk and Hudson, 2004).In addition, the choice modeling approach enables the researcher to estimate marginal values of non-market goods and services whose marginal valuations are impossible/difficult to measure (Ward *et al.*, 2013), or goods which are not yet on the market like new technologies which are still at the development stage (Arora *et al.*, 2017). CEs are advantageous because they closely simulate real-world purchasing decisions (Bell *et al.*, 2014). A respondent is given a hypothetical choice set with several alternatives, and is required to choose the preferred alternative. Each alternative is a combination of all the attributes, taking on different levels. In our case, the CE enabled us to elicit consumers' willingness to pay for quality traits (colour, taste, size, aroma and texture) embedded in sorghum. CEs have been applied to elicit what farmers want from Agri-environment scheme design (Espinosa-Goded *et al*., 2010), study consumer preferences for roasted peanut products in Haiti (Nelson *et al*., 2005), study farmer preferences for drought tolerance in hybrid *versus* inbred rice (Ward *et al*, 2013), study farmer preferences for abiotic stress tolerance in Hybrid versus Inbred Rice (Ward *et al*., 2013), estimate willingness to pay for irrigation water in Pakistan (Bell *et al*., 2014).

A choice experiment was designed first by defining sorghum grain in terms of its attributes and levels taken by these attributes. Our study focused on intrinsic attributes only. An initial list of attributes and their levels was generated in consultation with sorghum breeders at the National Semi-Arid Resources Research Institute Serere (NaSARRI). The breeders disclosed many sensory consumer attributes and levels that could be generated using sophiscated laboratory methods, but gave us only those relevant to farmers who are the major consumers. Accordingly, the breeders gave us five sensory attributes, namely; colour, taste, texture, grain size and aroma. Under the colour attribute, four colours were identified by the breeders, namely: deep blown/ red, light (blown), white and cream. Three levels of the taste were identified, the "sweetish" taste, 'intermediate' and the "bitter/ sour" taste. Taste in this regard is the sensation associated with sugars. *Atapa* with a sweetish taste has a slight sugar taste; whereas bitter/ sour taste appears as banana sap on the tongue. The intermediate taste is neither sweet nor bitter. Three levels of texture were identified, including elastic/extensible, intermediate and inelastic texture.

Texture refers to the feel of *atapa* when pressed between fingers and the fingers pulled apart. *Atapa* with elastic/extensible texture stretches; while intermediate stretches but not as much as the elastic one, and the inelastic one breaks when stretched but sticks on fingers instead. Three levels of grain size were identified – big, intermediate and small. The aroma attribute refers to the smell of *atapa*; while eating. The aroma attribute was assigned two levels by the breeders – the "good" and "not good" aroma. They simply used "good" and "not good" because it was difficult to describe the aromas. The list generated by the breeders was then availed to key informants in focus group discussions (FGDs) to verify whether the locals had a good understanding of the attributes and their levels as assigned by the breeders. The FGDs were constituted by 10 – 15 elderly people (above 45 years of age) being considered as key informants

because they had vast experience with sorghum foods, particularly *atapa*. One focus group discussion was conducted in each of the selected parishes, mainly to validate sorghum attributes. The FGDs maintained the five attributes, but with a variation in some attribute levels. Unlike the breeders at NaSSARI who identified three attribute levels for texture, FGDs could clearly identify two levels for texture, elastic and inelastic texture. They reported that they added cassava flour to sorghum flour before food preparation to create the desired elasticity.

For gain size, FGDs described two levels - small and big grain size. They could not put a distinction between intermediate and big grain size and referred to the two as big. Regarding taste and aroma, key informants in FGDs maintained three and two levels of taste respectively, as described by NaSSARI breeders. The variation in attribute level description between the key informants and NaSSARI breeders was only in texture and grain size (2 *versus* 3 levels).

Since the evaluation was to be done by consumers and the key informants represented consumers, it was prudent that we considered the attribute levels that were given in the FGDs. We wanted to ensure that respondents would able to relate to the attribute levels that were presented to them, a condition that is critical for guaranteeing success of a CE (Arora *et al*., 2010). In addition, we found a consistence between attributes identified by FGDs in our study and those in literature review (Kibekile *et al*., 2003; Makindara *et al*., 2013; Schipmann *et al*., 2013). Subsequently, five attributes with levels shown in Table 1 were used in the present CE. Additionally, monetary attribute and purchase price were included to capture the marginal WTP for the attributes. The middle prices (US$ 0.18 and US$ 0.27) were the actual minimum and maximum prices, respectively, observed in the study period. However, during focus group discussion, we inquired about the lowest that the price had ever dropped to in the last three years and US$

TABLE I. Sorghum grain attributes and attribute levels used in a choice experiment

Sorghum attribute	Attribute level	Description of the attribute level
Grain size	Small	Small grain size at harvest
	Big	Big grain size at harvest
Grain colour	(1) Red; (2) white;(3) Cream; (4) brown	The colour of the pericarp after drying the grains
Texture	Elastic	Elastic texture refers to the ability of *atapa* to stretch when squeezed between fingers and fingers separated
	Inelastic	Atapa breaks and sticks when squeezed between fingers and fingers separated
Taste	Bitter/sour taste	The taste of atapa in the mouth that is similar to sap of banana fingers
	Intermediate	A feeling of no taste when atapa is put in the mouth
	Sweet taste	Some sugarly sweetness of atapa while chewing
Aroma	'Good' aroma	The desirable smell of atapa while mingling and eating
	'Not good'	The undesirable smell of atapa while mingling and eating
Price (US$ kg^{-1})	(1) 0.11; (2) 0.18; (3) 0.27, (4) 0.45	The amount of money a respondent spends on purchasing a kilogram of sorghum grain for atapa consumption

0.11 was reported. Similarly, we asked for the highest that price had ever gone to and US$ 0.45 was reported.

Given the large geographical scope of the study and the cost of surveys of this kind, the CE was conducted through a two-stage procedure. First, a conventional fractional factorial orthogonal design (with the aid of NGENE 4 software) was used in a preliminary survey of 40 consumers to obtain prior coefficients. The prior coefficients (henceforth called priors) were estimates of a multinomial logit model (MNL) using data for the 40 consumers. The priors (specified with a normal distribution) were then used in the second stage to generate Bayesian efficient designs, also using NGENE 4 software. Bayesian designs allow taking into account uncertainty about the true value of priors used to construct the asymptotic variance-Covariance (AVC) matrix (ChoiceMetrics, 2012). In the second stage, a mixed logit model, whose random parameters follow a Bayesian normal distribution, was used to generate the final choice design. Several efficient designs were generated and one with the lowest D_b-error (hence D-optimal) was considered for the study. The D-optimality level was 85.7 percent. We specifically used the D-optimality criterion because it offers the advantage that the relative performance of different experimental designs is independent of the coding strategy or scale used (Vermeulen *et al.*, 2008). In addition, the design had a good utility balance (a B- estimate of 82 percent), which indicates that there was an insignificant likelihood of dominance by any alternative in the choice situations.

The final Bayesian design had 24 paired choice profiles that were randomly blocked into six sets of four choice tasks. The essence of blocking was to reduce the burden on survey respondents, while evaluating the alternatives in the given choice sets. Respondents were randomly assigned to one of the six sets. Each choice task consisted of two alternatives (A and B) and an "opt out" option (C). The opt-out option is our base variety with red colour, bitter taste, inelastic texture, 'not good' aroma and small grain size. These attribute levels are coded "0" (Table 3 for attribute coding). An example of a choice set presented to respondents is shown in Table 2.

Pilot testing of the CE questionnaire was conducted through face-to-face interviews of 12 respondents to refine its wording and format. The pilot survey showed that respondents could comfortably handle four choice tasks.

Theoretical framework. Consumer decisions from a Choice experiment are frequently analysed with a discrete choice model, based on the consumer theory developed by Lancaster (1966) and Rosen (1974), which

TABLE 2. Example of a choice set presented to the respondents for evaluation

Choose your most preferred type of variety from the following three alternatives

Grain attribute	Alternative A	Alternative B	Alternative C
Colour	Brown	Red	NO CHOICE
Taste	Good	Intermediate	
Texture	Elastic	Elastic	
Smell	Good	Good	
Size	Big	Small	
Price	UGX 400 (US$0.11)	UGX 650 (US$0.18)	
Which one would you prefer?	1 = Yes, 0 = N0	1 = Yes, 0 = N0	1 = Yes, 0 = N0

postulates that preferences of goods are a function of the attributes possessed by the good, rather than by the good per *se*. A consumer derives utility from a choice of product made. The choice that the respondent made was modeled as a function of the attributes using Random Utility Theory (RUT). Following McFadden (1974), we employ a random utility framework to analyse the choice responses to the different choice sets.

Assuming a linear indirect utility function, the utility of an individual *i* with *t* choice sets each with *j* alternatives is given by:

$$U_{ijt} = V(X_{ijt}) + \varepsilon_{ijt} \quad \text{..... (1)}$$

Where:

U_{Ij} is the latent unobservable utility level that the i^{th} consumer obtains from choosing the j^{th} grain type; V is the systematic/deterministic component that is a linear function of observable attributes (X_{ij}) and ε_{ij} a random component

The traditional conditional Logit (CL) model could be used to estimate the model in Equation 1 but the model is not only restrictive to the property of "Independence of Irrelevant Alternatives (IIA)" but also not able to capture individual preference heterogeneity (Kragt, 2013). In the real world, heterogeneity occurs as a result of varying consumer characteristics. This heterogeneity could be captured by interacting consumer observable characteristics with the observable attributes of the product (Vij and Krueger, 2017). However, even after inclusion of demographic variables, considerable heterogeneity would still remain (Revelt and Train, 1998). Chamberlain (1980) reported that some of the heterogeneity is attributed to unobservable consumer characteristics. This suggests that preferences vary considerably more than can be explained by observed consumer characteristics. Subsequently, we adopt a Mixed logit model (MXL) to incorporate random taste heterogeneity (Vij and Krueger, 2017). The MXL model also relaxes the IIA (Hensher and Greene, 2003). In addition, the MXL model accounts for dependence across a panel of repeated choices made by the same respondent (Train, 1998).

Following Revelt and Train (1998), the MXL model, given four choices presented to a respondent (T=4), each with three alternatives (*j* = A, B and an opt-out option), is specified as:

$$U_{ijt} = \alpha_i P_{ijt} + \beta_i' X_{ijt} + \varepsilon_{ijt}$$

j=1,2,3; t=1,2,3,4; ..... (2)

Where:

U_{ijt} is the utility obtained by individual *i* from alternative *j* in choice situation *t;* αi and βi are the individual-specific coefficients for the price and the other attributes of sorghum grain, and ε_{ijt} is a random error term. We assume that ε_{ijt} is extreme value distributed with variance given by $\mu_i^2(\pi^2/6)$, where μ_i is an individual-specific scale parameter. Dividing Equation 2 by does not affect behaviour and results in a new error term which is IID extreme value distributed with variance equal to Train and Weeks, 2005).

$$U_{ijt} = \lambda_i P_{ijt} + C_i' X_{ijt} + \varepsilon_{ijt}; \quad \text{..... (3)}$$

Where:

$$\lambda_i = \alpha_i/\mu_i \text{ and } C_i = \beta_i/\mu_i^2$$

This specification is what Train and Weeks (2005) refer to a model in preference space. Given this specification, the willingness to pay (WTP) for an attribute is calculated as a ratio of attribute coefficient to the price coefficient (Hanemann, 1984) (Equation 4). The distribution of WTP is derived from the estimated distribution of the non-price attribute coefficient to the price coefficient.

$$WTP = -1 * \left(\frac{C_k}{\lambda_i}\right), \quad k = 1, \ldots, 7 \quad \text{..... (4)}$$

Where:

C_k is the estimated coefficient for an attribute level in the choice set; and λ_i is the marginal utility given by the coefficient of the price attribute (using coefficients derived from specification 3).

The limitation with the preference space model specification is that it only accounts for unobserved preference heterogeneity, but assumes constant scale heterogeneity (Train and Weeks, 2005). It assumes that the standard deviation of unobserved utility is the same for all observations (ibid). It has been found out that failure to account for scale heterogeneity may lead to erroneous model estimates and hence inappropriate policy conclusions (Scarpa *et al.*, 2008). Train and Weeks (2005) suggest model re-parameterisation as a way of accounting for scale heterogeneity. In the re-parameterised model, the model parameters are the (marginal) WTP for each attribute rather than the utility coefficient of each attribute. The model allows the researcher to specify the WTP distribution directly and, therefore, avoids the rather arbitrary choice of WTP distribution that arises from dividing the coefficients of the non-monetary attributes by the price coefficient (Train and Weeks, 2005). Subsequently, the re-parameterised model produces more plausible estimates of willingness-to-pay (Train and Weeks, 2005; Sonnier *et al.*, 2007; Balcombe *et al.*, 2009) than the non-re-parameterised preference space model.

Following Train and Weeks (2005), Equation 3 can be re-parameterised by using the fact that WTP for the attributes (γ_i) is given by C_i/λ_i. Substitution into Equation 3 gives a new WTP space model specified as:

$$U_{ijt} = \lambda_i\left[P_{ijt} + \gamma_i' X_{ijt}\right] + \varepsilon_{ijt} \quad \text{..... (5)}$$

An alternative to Trains and Weeks' (2005) way of accounting for scale heterogeneity is by using a Generalised Mixed Logit model (GMXL) (Louviere and Eagle, 2006; Boeri *et al.,* 2011). The model has been used by Fiebig *et al.* (2009) to account for both preference and scale heterogeneity. Following Fiebig *et al*. (2009), the GMXL model is specified as:

$$U_{ijt} = [\sigma_i\beta + \gamma\eta_i + (1-\gamma)\sigma_i\eta_i]'X_{ijt} + \varepsilon_{ijt}; \quad \text{..... (6)}$$

Where:

σ_i is the individual specific standard deviation of the idiosyncratic error term capturing scale heterogeneity; η_i is individual specific deviations from the mean, capturing individual heterogeneity in preferences; and γ is a parameter between zero and one, that can capture how the variance of the individual preference heterogeneity varies with scale.

Fiebig *et al*. (2009) suggest a number of normalisations that are required to estimate the GMXL model specification (6). Firstly, σ_i is normalised as $\sigma = -\tau^2/2$ to enable identification of σ, so that $E[\sigma_\tau^2] = 1$. τ is the parameter that captures scale heterogeneity. Furthermore, to ensure that $\tau > 0$, the model is fit in terms of λ, where $\tau = \exp(\lambda)$ and λ is unrestricted (Hensher *et al.*, 2011). If τ approaches zero, the GMXL model approaches the ML model (Fiebig *et al*., 2009).

The overall WTP or compensating surplus (CS) welfare measure, which is the total of WTPs for all the attributes, was obtained from:

$$CS = -1 * \frac{(V_1 - V_0)}{\beta_8} \quad \text{..... (7)}$$

Where:

V_1 represents the value of the indirect utility associated with attributes of a variety under consideration, V_0 is the indirect utility of the

base variety. V_1 and V_0 are obtained by adding up the estimated coefficients of the levels of traits that make up the profiles.

Empirical Mixed logit model specification. Given four choices presented to a respondent (T = 4), each with three alternatives (j = A, B and an opt-out option), the empirical model was specified as:

$$U_{ijt} = \alpha + \beta_{i1}X1_{ijt} + \beta_{i2}X2_{ijt} + \beta_{i3}X3_{ijt} + \beta_{i4}X4_{ijt} + \beta_{i5}X5_{ijt} + \beta_{i6}X6_{ijt} + \beta_{i7}X7_{ijt} + \beta_{i8}X8_{ijt} + \varepsilon_{ijt} \quad \ldots\ldots (8)$$

The variables used in the analysis and their coding are shown in Table 3. During model estimation, all the attributes' parameters (except price) were treated as random parameters, and were specified to be normally distributed, since a normal distribution allows preferences to range between positive and negative for a given attribute (Train, 1998). The parameter for the price attribute was treated as a fixed parameter and assumed to have been drawn from a continuous distribution.

RESULTS AND DISCUSSION

Table 4 shows results from the mixed logit (MXL) model (M1), generalised mixed logit model (GMXL) in utility space (M2); and the generalised mixed logit model in willingness to pay space (M3). All the three models are specified by controlling for correlation among the set of random parameters, and indeed some elements of the Cholesky matrix (second part of Table 4) show strong evidence of correlated attributes. The reason for controlling for correlation is that mixed logit models with full correlation among utility coefficients allow for all sources of correlation, including scale heterogeneity (Hess and Train, 2017).

Basing on the overall goodness of fit (pseudo-R^2), M3 fits the data better than M1 and M2 fitted in the preference space. This is further indicated by the log likelihood value at convergence for M3 (-498.64) compared to -502.0 and -883.8 for M1 and M2, respectively. The findings are consistent with those of Scarpa *et al*. (2008) and Balcombe *et al*. (2009), who reported a better statistical fit when using models fit in WTP space. Notwithstanding, we discuss consumer preferences using results obtained from models estimated in the preference space (M1 and M2), and revert to M3 when it comes to discussing WTP.

Sample results from models estimated in preference space indicate that taste, texture, aroma and grain size had a positive and statistically significant effect on consumers' preference. The results were consistent with those of Kayode *et al.* (2005) and Kayode *et al.* (2006), who reported that consumers make choice of sorghum food products basing on

TABLE 3. Description of variables used in the choice analysis

Variable	Variable label	Variable coding
X1	ColorB	(1= brown colour of grains, 0 = otherwise)
X2	ColorW	(1 = white colour of grains, 0 = otherwise)
X3	ColorC	(1 = Cream colour of grains, 0 = otherwise)
X4	Taste	(1 = sweet taste of 'atapa', 0 = otherwise)
X5	Text	(1 = elastic texture of 'atapa', 0 = otherwise)
X6	Aroma	(1 = good smell of 'atapa', 0 = otherwise)
X7	Size	(1 = big size of grains, 0 = otherwise)
X8	Price	Price in US$ per kilogram (0.11, 0.18, 0.27, 0.45)

TABLE 4. Mixed Logit models estimates of grain attributes preferred by sorghum consumers

Variable	Mixed logit model in) utility space (M1	Generalised MXL model in utility space (M2)	Generalised MXL model in WTP space (M3)
Brown	-0.362(0.47)	-0.362(0.25)	-0.09(0.09)
White	0.010(0.44)	0.010(0.28)	-0.03(0.09)
Cream	0.214(0.38)	0.214(0.25)	-0.02(0.10)
Taste	3.095(0.57)***	3.095(0.19)***	0.69(0.21)***
Texture	1.353(0.38)***	1.353(0.25)***	0.25(0.09)***
Aroma	1.361(0.38)***	1.361(0.37)***	0.39(0.14)***
Size	0.837(0.33)**	0.837(0.36)**	0.18(0.10)*
Price	-0.0011(0.0003)***	-0.015(0.005)***	*Fixed*
Diagonal values of the Cholesky matrix			
Brown	2.187(0.45)***	2.187(0.75)***	0.37(0.14)***
White	2.187(0.45)***	2.187(0.75)***	0.37(0.14)***
Cream	2.187(0.45)***	2.187(0.75)***	0.37(0.14)***
Taste	1.559(0.63)**	1.559(10.09)	0.11(0.18)
Texture	0.395(0.48)	0.395(8.01)	0.18(0.15)
Aroma	0.246(0.68)	0.246(10.89)	0.14(0.17)
Size	0.678(0.74)	0.678(6.53)	0.08(0.16)
Price	Fixed	1.946(0.006)***	Fixed
Standard deviations of parameter distributions			
Brown	2.187(0.45)***	2.187(0.75)***	0.37(0.14)***
White	2.934(0.62)***	2.252(1.17)*	0.39(0.14)***
Cream	2.517(0.53)***	3.264(1.70)*	0.48(0.16)***
Taste	3.158(0.78)***	2.339(9.73)	0.49(0.19)***
Texture	1.444(0.48)***	1.708(8.61)	0.31(0.17)*
Aroma	2.116(0.63)***	1.883(10.08)	0.38(0.18)**
Size	2.194(0.63)***	2.192(8.22)	0.38(0.19)**
Price	Fixed	1.947(0.006)***	Fixed
Tauscale		0.100(0.05)***	0.1 (fixed)
Gamma		0.100(0.42)	0 (Fixed)
Sigma_i		0.999[0.10]	0.99396 (0.097)***
Parameter for price (WTP space)			
Beta_WTP			-0.0021(0.0008)***
S_WTP			0.0013(0.0007)*
Log Likelihood at convergence		-502.015	-883.800 -498.637
R^2	0.238		0.243
AIC	1072.0	1855.6	1067.3

Statistical significance levels: ***1%; **5%. Corresponding standard errors are shown in parentheses

texture, taste and aroma. The colour attributes had no statistically significant effect on consumer preference. This is inconsistent with the findings of Mafuru *et al*. (2007) and Laswai *et al*. (2003) that colour significantly affects acceptability of sorghum foods. The non-significance of the colour attributes is consistent with findings of Melton *et al*. (1996) that colour was likely to matter, especially to first time purchasers of sorghum for food, but repeated purchases were more likely to be influenced by taste (ibid). This is plausible in our case since sorghum is a staple food in the area and the respondents are not first time consumers of sorghum. Indeed, we find taste (sweet) to have the largest positive coefficient, implying that it has the highest preference among consumers. Consistent with Kayode *et al* (2005), taste is the most important criteria for evaluation quality of all sorghum based foods (pastes, porridges and beverages). The afore-mentioned authors found out that consumers in Benin prefer *dibou (dibou* is a local name for sorghum paste in Benin) that is slightly sweet. The aroma attribute had the second largest positive effect.

The positive effect of texture was due to consumers' reported preference (during focus group discussions) for '*atapa*' that is elastic. The key informants reported that they prefer '*atapa*' which is elastic/extensible because it does not stick on fingers while eating. Respondent's preference for elastic *atapa* is consistent with what Kayode *et al.* (2005) that a good *dibou* must be elastic/extensible if it is to be regarded as of good quality in Benin. Rooney *et al*. (1986) also found, texture to be one of the most important characteristics affecting sorghum food quality. Grain size also had a positive and statistically significant effect on consumer preference. This implies that the bigger the grain, the more it was preferred by consumers. Respondents reported that they preferred sorghum with big grain because it yielded more flour after milling. This is consistent with a study done by Wills *et al*. (1992) to examine sorghum grain samples for food in Australia, which found out that grain size was quite important for food usage. Kayode *et al*. (2006) also found large grains of sorghum to be preferred by consumers in Benin because large seeds yield a high volume. The price attribute had a negative and statistically significant effect consumers' preference. The negative price coefficient implies that, on average, the higher the price, the less likely a given variety would be chosen. The high and statistically significant standard deviations (part 3 of Table 4) revealed that preferences for sorghum attributes vary (heterogeneous) in the population for all the attributes with respect to M1.This implies that the attribute coefficients are not fixed, but significantly varied across individuals, hence taste heterogeneity. Besides taste heterogeneity, scale heterogeneity was also found to be present, as evidenced by the statistically significant variance parameter for scale (tau) equal to 0.100.

The parameter estimates of the re-parameterised model (M3 in Table 4) are the direct WTP estimates for the attributes. With respect to M3, the non-colour attributes had positive and statistically significant WTP estimates, implying a price premium on the attributes. This is consistent with WTP estimates obtained from a two-step process of M1 and M2 (Table 5). However, for plausibility as stated by Scarpa *et al.* (2008) and Balcombe *et al*. (2009) that a re-parameterised model is better, we discuss WTP estimates obtained from M3.

Sample results indicate that consumers were willing to pay the highest price for sweet taste attribute (US$ 0.69 per kilogramme) followed by 'good' aroma (US$ 0.39). Consumers were also willing to pay a premium for elastic texture and big grain size attributes. The WTP estimates for the colour attribute are not only negative, but insignificant. This could mean that colour is not important for sorghum consumers.

The overall WTP or compensating surplus (CS) welfare measure was obtained for five

hypothetical varieties (Table 6) to illustrate how consumers might respond to varieties with different combinations of attributes. CS is the total WTP for a given variety and is obtained by adding the WTP estimates for the individual attribute. The attributes with "Ø" symbol indicate attribute level with code "1" and where this symbol is not indicated, it is an attribute level with code "0" (refer to Table 3 for attribute coding). For example, variety 2 is: "white" colour (code 1), bitter or intermediate taste (code 0), "elastic" texture (code 1), 'not good' aroma (code 0) and "small" grain size (code 0).

The total WTP for all the five hypothetical varieties was positive, implying consumers' willingness to pay premiums for the varieties. Among the five hypothetical varieties, 3, 4 and 5 turned out with the largest total willingness to pay value. The high total WTP of the three varieties is attributed to the presence of the highly preferred consumer attributes (good taste, elastic texture, good aroma and big grain size). The three varieties only differed in colour. This implies that in the presence of the highly preferred attributes, colour less important. Moreover, Kayode *et al.* (2006) found no significant differences in consumers' preference for sorghum grain colour over another colour.

The actual attribute levels that constituted the five hypothetical varieties in Table 6 are presented in Table 7. Each row is a variety (hypothetical) with different attribute levels. For example, variety 3 is a grain variety with brown colour, sweet taste, elastic texture, good

TABLE 5. Marginal WTP estimates for the sorghum quality attributes (US$ per Kilogramme)

Variable	WTP estimated from M1	WTP estimated from M2	WTP estimated from M3
Brown	-0.09(0.10)	-0.01(0.01)	-0.09(0.09)
White	0.00(0.11)	0.00(0.00)	-0.02(0.09)
Cream	0.05(0.10)***	0.00(0.00)	-0.02(0.10)
Taste	0.75(0.22)***	0.05(0.02)***	0.69(0.21)***
Texture	0.33(0.10)***	0.02(0.01)***	0.25(0.09)***
Aroma	0.33(0.11)***	0.02(0.01)**	0.39(0.14)***
Size	0.20(0.10)*	0.01(0.01)*	0.18(0.10)*

Standard errors in parentheses; superscripts a,b,c indicate significance at 1%, 5%, 10% respectively.

TABLE 6. Attribute levels and compensating surplus for hypothetical sorghum grain varieties (in US$)

Variety	Attribute							Total
	Brown	White	Cream	Taste	Texture	Aroma	Size	WTP/CS
1	Ø					Ø		0.30(0.20)
2		Ø			Ø			0.22(0.15)
3	Ø			Ø	Ø	Ø	Ø	1.41(0.51)***
4		Ø		Ø	Ø	Ø	Ø	1.48(0.52)***
5			Ø	Ø	Ø	Ø	Ø	1.49(0.50)***

Notes: Standard errors are in parentheses. Ø indicates attribute level with code '1', otherwise code '0'.

TABLE 7. Actual attribute combinations for the hypothetical varieties

Attribute Variety	Colour	Taste	Texture	Aroma	Grain size	CS (US$)
1	Brown	Bitter	Not elastic	Good	Small	0.30
2	White	Bitter	elastic	Not good	Small	0.22
3	Brown	Sweet	Elastic	Good	Big	1.41
4	White	Sweet	Elastic	Good	Big	1.48
5	Cream	Sweet	Elastic	Good	Big	1.49

aroma and big grain size and consumers would be willing to pay US$ 1.41 (Ugx 5,223) per kg for such a variety.

CONCLUSION

The study revealed that non-colour attributes (taste, texture, aroma and grain size) were more important for sorghum consumers. Of the four attributes, sweet taste and good aroma were greatly preferred. Consumers are also willing to pay a significant price premium for the preferred attributes. Consumers were willing to pay highest for the sweet taste; followed by a good aroma. The preference for colour was not significant. This means that consumers could accept any variety (regardless of colour) provided it has the four preferred attributes. This is evidenced in the total willingness to pay computed for hypothetical variety 3, 4 and 5. The three varieties were different in colour, but had significantly high total implicit prices due to the presence of the four desired attributes.

There was considerable taste and scale heterogeneity among sorghum consumers. Taste heterogeneity implies that consumers had varying sorghum taste patterns. Exploring source of taste heterogeneity was beyond the scope of this study, most especially when literature already suggests that even inclusion of demographic variables still leaves considerable heterogeneity. The presence of scale heterogeneity implies that there was a significant variation across sorghum consumers in the impact of unobservable consumer characteristics.

ACKNOWLEDGEMENT

We acknowledge the BIO-INNOVATE project funded by the Swedish International Development Cooperation Agency (SIDA) for funding data collection and analysis. Grant code: MKU01

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