

Toward understanding household preference for consumption characteristics of millet varieties: a case study from western Niger

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Abstract

In this study, we evaluate the preference of consumers in Niger for different *tuwo* or *couscous* characteristics using a random utility-based choice experiment, ordered probit analysis, and tree-based partitioning. Data were collected through a structured survey administered at four sites. Preferences are estimated for three products (*couscous*, fermented *tuwo*, and nonfermented *tuwo*) made from five pearl millet cultivars. We provide relative valuation for different traits by type of product. Results show that product taste, color, and textural attributes are important, especially for *tuwo* and *couscous*. Probit and partitioning results show that taste and color are the first attributes that consumers use to distinguish more preferred millet food products from less preferred millet food products. This should provide some direction for millet breeding programs and food processing of millet.

JEL classification: D1; O1; Q1

Keywords: Pearl millet genetics; Characteristics; Random utility; Ordered probit; Food processing

1. Introduction

Pearl millet (*Pennisetum glaucum* L. Br.) is the primary food source for millions of people in the semi-arid tropics of West Africa. In Niger, pearl millet accounted for 77% of per capita consumption on average between 1994 and 1996 (Nelson and Ndjeunga, 1999). Pearl millet ranks first in terms of total cereal cultivated and production. It represented 72% of total cereal area and 80% of total cereal production in Niger for the period 1995–1997. Pearl millet is a subsistence crop, mainly consumed in the form of thick porridges

(e.g., *tuwo*¹), thin porridges (e.g., *fura*, *coco*, *bita*), cakes (e.g., *massa*), or steamed granulated products such as *couscous*² (ROCAFREMI, 1997).

¹ *Tuwo* is a stiff porridge made from sorghum, pearl millet, maize, rice, or finger millet flour. It is known in different countries by names such as *tuwo* in Niger, *tô* in Burkina Faso and Mali, *askfor* or *eko tutu* in Nigeria, *ugali* in Kenya, *atab* in Uganda, *aceda* in Sudan, *bogode jiva ting* in Botswana, *tuo jaafi* in Ghana, and *sakanti* in India (Aboubakar, 1992; Murty and Kumar, 1995). *Tuwo* is usually eaten with fingers and is accompanied by some types of sauce or stew made of many ingredients. The ingredients used vary among countries and their uses are dependent upon cost and availability. In Niger, the major ingredients used in the preparation of the sauce include tomato, okra, or baobab leaves and meat (Aboubakar, 1992).

² *Couscous* is a steamed granulated product made from sorghum, pearl millet, maize, fonio, or wheat. For immediate use, the product

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Breeders have developed more than 17 improved pearl varieties in Niger³ (INRAN, 1984). But few of these varieties have been adopted by farmers. Poor adoption of improved varieties is partially explained by seed supply and demand constraints of the available varieties. Seed supply constraints in West Africa have been well researched. They include the low supply of breeder seed, poor seed demand estimation, poor distribution systems, and low seed quality (Ndjeunga, 1997). In contrast, variety-specific demand constraints for millet have not been thoroughly researched. Demand for varieties is a function of plant, grain, and cooking traits preferred by farmers that are embodied in the varieties. The plant and grain traits preferred by farmers have been investigated for pearl millet and groundnut in Niger (Baidu-Forson, 1997; Baidu-Forson et al., 1997). Sorghum cooking traits have been well researched as well (Aboubakar, 1992; Boling et al., 1982; Da et al., 1982; Gebrekian and Gebre-Hiwot, 1982; Jeannette et al., 1987; Mukuru et al., 1982; Obilana, 1982; Scheuring et al., 1982). However, knowledge of pearl millet cooking traits preferred by consumers is still limited. Farmers' rejection of varieties may be due to their poor cooking traits (Robins, 1995). Therefore, knowledge of traits preferred by consumers is valuable for crop improvement programs and provides market signals for food processors. The demand for improved pearl millet varieties is likely to increase if, among others, varieties are designed to include producers' and consumers' preferred cooking traits. Improving the performance of varieties in terms of cooking quality traits will contribute to the productivity, efficiency, and profitability of pearl millet production in Niger.

This study systematically evaluates the preferences of consumers for *tuwo* and *couscous* cooking quality characteristics. It uses ordered probit analysis and tree-based partitioning to measure the value of *tuwo* and *couscous* cooking quality characteristics. Random utility-based choice experimentation is a survey-based valuation technique, widely used in marketing

is sprinkled with water and mixed thoroughly after adding baobab (*Adansonia digitata* L.) leaf powder or okra powder. This flour aggregate mixture is again steamed for about 25 minutes to give the *couscous* product a light texture. (Murty and Kumar, 1995).

³ A large number of other improved pearl millet varieties are awaiting release in Niger. They are listed as: ICMV89305, ICMV 92222, ICMV 94206, GB 8735, MTDO92, MTTY92, and CTO-V.

research, which relies on individuals' background and judgment of products to estimate the marginal contribution of specific product traits to overall preferences. Random utility-based preference elicitation provides an analysis of preference that is consistent with actual choice, and is founded in a behavioral theory (Louviere, 2001). Consumer's relative preferences for attributes are estimated with ordered probit models. Tree-based partitioning is a rigorous statistical classification procedure that supplements the results of ordered probit models by producing information about the order in which attributes lead to preference distinctions.

2. Empirical design and data collection

The development of a survey instrument to generate data that would allow the analysis of the independent effects of mutually exclusive consumption attributes involved a number of steps. First, available literature on prior economic and food science analyses of consumer preference for attributes was reviewed to develop a list of important *tuwo* and *couscous* characteristics for potential inclusion in the questionnaire. Texture, color, taste, and keeping quality are often cited as *tuwo* quality characteristics that are important for sorghum consumers (Aboubakar, 1992; Boling and Eisener, 1982; Da et al., 1982; Fliedel et al., 1998; Gebrekian and Gebre-Hiwot, 1982; Mukuru et al., 1982; Murty et al., 1982; Obilana, 1982; Scheuring et al., 1982). Few sensory studies have been documented on pearl millet quality. A study undertaken on *couscous* quality characteristics in three villages in Niger indicated that color, taste, and texture were the most important quality traits (Oumarou et al., 1998). These characteristics, likely to be preferred by consumers, were used to conduct a focus group meeting with pearl millet consumers from two villages: Berikoira and Tagabati. The meetings were conducted to evaluate alternative question formats and contents, and to elicit general advice about mutually exclusive traits desirable to consumers. The information from the focus group meetings was used to classify consumption attributes into unique mutually exclusive categories (Louviere, 1990, p. 51). The last stage was the development of the survey instrument.

The characteristics included in the survey instrument were those ranked high in the focus group meetings.

In general, a *couscous* of light color (white cream or yellow), with a nice aroma and taste, and with a good overall texture is likely to be most preferred. Texture is a composite of cohesiveness, stickiness, and chewiness. A *couscous* that does not feel hard to the touch, is not sticky, and is not hard to chew would have good texture. A *tuwo* with light color, good taste, good texture, and good overnight keeping quality is likely to be preferred by consumers. Taste has been found to be strongly influenced by color and texture. The desirable textural attributes are hardness, cohesiveness, and adhesiveness. Because *tuwo* is eaten with fingers it should be firm enough to scoop a piece that holds together and does not crumble under finger pressure. Consumers do not want *tuwo* to stick to the fingers, teeth, or palate. *Tuwo* left over from a meal is often stored overnight, and consumed the following day. Thus, a good *tuwo* should remain stiff during overnight storage.

The survey included 7 *couscous* characteristics and 11 *tuwo* characteristics. *Couscous* products were evaluated on the basis of: color (disliked, liked); aroma (disliked, liked); cohesiveness (soft, just right, hard); stickiness (not sticky, just right, too sticky); taste (disliked, liked); chewiness (disliked, liked); and texture (disliked, liked). *Tuwo* products were evaluated on the basis of: color (disliked, liked); appearance-interior (disliked, liked); aroma (disliked, liked); cohesiveness (soft, just right, hard); stickiness (not sticky, just right, too sticky); consistency (disliked, liked); taste (disliked, liked); the way the *tuwo* dissolves in the mouth (slow, just right, fast); chewiness (disliked, liked); texture (disliked, liked); and *tuwo* overnight keeping quality (not consistent, just right, too consistent). The aggregate attribute texture was included as a preference consistency check. Respondents evaluated *couscous* and *tuwo* made from five different varieties, ranking the varieties on a 5-point preference scale (1 being the least preferred and 5 being the most preferred). *Tuwo* and *couscous* products were processed from five pearl millet varieties: four improved varieties, MTDO92, Zatib, Souna III, and CTO-V, and a local cultivar, Hainikiré. These cultivars were recommended by pearl millet breeders and food technologists and varied in pericarp color and endosperm texture. The improved cultivars were grown in the Dosso department in Niger during the 1998 crop season. Traditional technology was used to process all products. In each site and for each variety, a local woman was hired to decorticate the grain,

mill the decorticated grain into fine flour, and process the flour into *tuwo* or *couscous*.⁴

The panellists used in this experiment were a mixture of literate and illiterate adults, averaging 44 years of age. A total of 114 panellists were selected on the basis of ethnicity, gender, and urbanization. About half the consumers were adult female. Two-thirds of the panel came from the Zarma ethnic group and about one third from the Haoussa ethnic group. About one third of the panellists were literate. More than 80% of the zarma ethnic group panellists and 50% of the haoussa ethnic group panellists ate *tuwo* or *couscous* at least once a day, respectively. Table 1 presents a summary of the characteristics of the survey sample gender, age, household size, ethnic group, level of education, and daily consumption frequency of *tuwo* or *couscous*.

During the first two days of the survey, enumerators collected information on the respondents' socioeconomic profile. During the third day, panellists familiarized themselves with the terminology used and the ranking scales. Tests were carried out at ambient temperature in three separate rooms with one enumerator and a food technologist per room. Panellists were asked to avoid communication during the test. On each of four successive days, the panel evaluated five nonfermented *tuwo* samples made from the five pearl millet varieties. The next day, panellists were asked to evaluate the overnight keeping quality of the *tuwo*. The same day, respondents also evaluated five *couscous* products made from the same five pearl millet varieties. During the last two days, the panellists were asked to evaluate five fermented *tuwo* products and their keeping qualities.

The local variety control for all products was the pearl millet variety used in the village. In each case, the local cultivar *Hainikiré* was used. Each of the panel members evaluated the product using the cards presented in Table 2 for *tuwo* and in Table 3 for *couscous*. The questionnaire covered all relevant attributes of *tuwo* and *couscous*. The tables indicate that different attributes were evaluated at different stages of food preparation and consumption. For example, the cohesiveness of *tuwo* is evaluated when a piece of *tuwo* is cut, and the stickiness is evaluated after the piece

⁴ Details about the preparation of *tuwo* and *couscous* can be obtained from the authors on request.

Table 1
 Characteristics of consumer surveyed in Niger

Survey site	Berikoira	Karabedji	Gaweye	Chikal	Total
Sample size	30	30	25	29	114
1. Distribution of respondents by gender					
Men	15	15	13	15	58
Women	15	15	12	14	56
2. Age distribution in years					
Average (years)	45	41	45	46	44
≤30 years	3	4	2	3	12
30 years	27	26	23	26	102
3. Average household size	13	9	6	11	10
Less than 4 members per household	0	1	6	1	8
Between 4 and 8 members	8	15	16	12	51
More than 8 members	22	14	3	16	55
4. Ethnic groups					
Zarma	30	30	18	0	78
Haoussa	0	0	1	29	30
Others (Gourma, Gaboro, Peulh, Dendi)	0	0	6	0	6
5. Level of education					
Illiterate	21	25	13	24	83
Literate ^a	9	5	12	5	31
6. Daily consumption frequency for					
<i>Tuwo</i>					
Less than 1 <i>tuwo</i> per day	0	0	5	15	20
More than 1 <i>tuwo</i> per day	30	30	20	14	94
<i>Couscous</i>					
Less than 1 <i>couscous</i> per day	14	12	12	21	59
More than 1 <i>couscous</i> per day	16	18	13	8	55

^aIncludes all panellists with koranic, primary, or secondary education.

of *tuwo* has been worked up in the hand. Due to time constraints faced by consumers in urban Niamey, the fermented *tuwo* test could not be implemented. Thus, results reported for fermented *tuwo* cover three sites: Berikoira, Karabedji, and Chikal.

3. Theoretical framework

The survey data were analyzed with a random utility behavioral model of consumption that explains variety choice by preferences for product characteristics, as in the Lancasterian theory of consumer choice (Hamath et al., 1997). This characteristic-based choice model was used to evaluate preference for *tuwo* and *couscous* characteristics. In this model, the characteristics of the goods generate utility for consumers (Lancaster, 1991). The specification of intrinsic properties of goods as arguments of the utility function, and the possibility of confining analysis to goods that yield common

characteristics are important in empirical demand analysis (Ratchford 1975).

Let U represent utility for an individual. Utility is hypothesized to be a function of various factors, including the characteristics of the products, S , the individuals' socioeconomic background, Z , and an interaction term between the individuals' background and the products' characteristics, μ . The decision maker will choose the product that provides the highest utility (Train, 1986). That is, the decision maker will choose product j over j' if and only if $U_j > U_{j'}$. The utility function can be formally written as

$$U_j = f(S_{1j}, S_{2j}, \dots, S_{gj}; Z_1, Z_2, \dots, Z_i; \mu_1, \mu_2, \dots, \mu_{gji} | \Theta_g) + e \quad (1)$$

where $j = 1, 2, \dots, m$; $g = 1, 2, \dots, k$; $i = 1, 2, \dots, n$. Here j represents the product from a given variety; g the preference traits for the product, and i each consumer's socioeconomic characteristics. The variables s and Z

Table 2
Typical card for *tuwo* from the survey

Variables	Product <i>i</i> (<i>i</i> = 1, 2, ..., 5)
Look at the <i>tuwo</i> , don't touch or cut it.	
How much do you like the color?	Liked/disliked
Cut of piece of <i>tuwo</i> , but don't eat it.	
Do you like the way the interior looks?	Liked/disliked
Do you like the aroma?	Liked/disliked
How hard is the <i>tuwo</i> ?	Soft/just right/hard
Take a piece of <i>tuwo</i> and work up the piece with your hands.	
How do you like the way the <i>tuwo</i> holds together?	Liked/disliked
How sticky is the <i>tuwo</i> to your fingers?	Not sticky/just right/sticky
Now, eat as much <i>tuwo</i> as you want and tell me:	
How do you like the taste?	Liked/disliked
How do you like the chewiness?	Liked/disliked
How quickly does it dissolve in your mouth?	Slow/just right/fast
How do you like the overall texture?	Liked/disliked
How do you like its consistency after a night?	Liked/disliked
Rating of the products tested?	

are the main effect variables representing the products' attributes and the individuals' profile, respectively. The term $\mu_{gji} = S_{gj} \times Z_i$, is the interaction variable between the products' characteristics and individuals' profiles. Since only a portion of the arguments in the above equation is observed, the equation is stochastic and variable e is a spherical disturbance term. The parameter estimates are represented by the vector Θ_g .

Table 3
Typical card for *couscous* from the survey

Variables	Product <i>i</i> (<i>i</i> = 1, 2, ..., 5)
Look at the <i>couscous</i> , don't touch it.	
How much do you like the color?	Liked/disliked
Take a piece of <i>couscous</i> , but don't eat it.	
How much do you like the aroma?	Liked/disliked
How hard is the <i>couscous</i> ?	Soft/just right/hard
Take a piece of <i>couscous</i> and work up the piece.	
How sticky is the <i>couscous</i> to your fingers?	Not sticky/just right/sticky
Now, eat as much <i>couscous</i> as you want and answer the following questions.	
How much do you like the taste?	Liked/disliked
How much do you like the chewiness?	Liked/disliked
How much do you like the overall texture?	Liked/disliked
Rating of the products tested?	

Market researchers have used different approaches, compositional and decompositional, to estimate the vector Θ_g . The decompositional approach uses measures of preference (e.g, a ranking) for multivariate alternatives or products to estimate the values attached to underlying characteristics. The partial derivative of the j th product (e.g., *tuwo*) with respect to the products' characteristics (e.g., color), gives the value of the partworth that the consumer assigns to the g th characteristic level of the j th product (Louviere, 1990). Since the utility of a product to an individual is a function of both the product's characteristics and the individuals' profile, the partworth is a joint effect of the two variables (Moore, 1980). For example, the change of utility of a *tuwo* to a consumer is determined by the variation of the *tuwo* characteristics and background of the consumer. More formally,

$$\frac{\partial U(s^*)}{\partial S_g} = \frac{\partial f(\cdot)}{\partial S_g} + \frac{\partial f(\cdot)}{\partial \mu_g} \times \frac{\partial \mu_g}{\partial S_g} \tag{2}$$

where the first side of the equation is the partworth of the g th level of the characteristic of a product to a given individual. It is composed of two parts. The first, the marginal value of the g th attribute level, measures the changes in the utility when only product attributes levels are allowed to vary and will be referred to as V_g . The second part is a product of two partials. The first term measures the variation in the utility associated with changes in the interaction term. It is also referred as the weight factor (b_g). The second term of the combination, Z_i , represents an individual's socioeconomic background. In general, the partworth of a product's attribute to an individual can be represented easily by

$$\frac{\partial U(s^*)}{\partial S_g} = V_g + Z_i \times b_g. \tag{3}$$

The weight factor, b , is hypothesized to take any value from negative infinity to positive infinity and captures the variability in preferences for a product due to the interaction between a person's background and product attributes. This is a direct measure of segmentability of the market. People with the same b coefficient have similar preferences, and hence can be grouped into one segment. Partially differentiating equation (1) with respect to individuals' profiles, gives variations in the utility that are accounted for by variation in socioeconomic variables across individuals. In

many cases, one is not interested at all in the main effects due to personal attributes, since the main effects may only reflect response biases (Green and DeSarbo, 1979). The relative importance of products for respondents can be computed using estimates from equation (1). For example, how important is one *tuwo* attribute relative to all other *tuwo* characteristics? The formula for the relative importance is

$$\psi_a = \frac{[\max(v_{ga}^*) - \min(v_{ga}^*)]}{\sum \omega_a} \quad (4)$$

where v_{ga}^* is the marginal value of the g th level of the a th attribute, ψ_a represents the relative importance for the a th attribute, $\sum \omega_a$ is the sum of all ranges $[\max(v_{ga}^*) - \min(v_{ga}^*)]$, across all attributes. ψ_a for a consumer can be normalized to ascertain its relative importance with regard to the other attributes and across consumers (Jain et al., 1979).

4. Estimation technique and the econometric model

OLS estimation is sometimes employed to analyze choice experiments, despite its limitations in analyzing data with categorical dependent variables⁵ (Doyle, 1977). The linear probability model is a procedure for discrete dependent variables, but it has a number of shortcomings. The error term is heteroskedastic, so it produces inefficient estimates (Greene, 1990, p. 663). Because of these difficulties, an ordered probit model will be specified and estimated. The specified model consists of U as an unobservable dependent variable, R_r (where $\gamma = 0, 1, 2, 3, \dots, w$) as the choice alternative or observable dependent variable, v and μ as the block of independent variables, and γ as the threshold variable. It can be formulated as

$$U = \alpha + Sv + \mu b + e \quad (5)$$

where $e \sim N(0, 1)$ and $R = 0$ if $U \leq 0$, $R = 1$ if $U \leq \gamma_1$, $R = 2$ if $\gamma_1 \leq U \leq \gamma_2$, ..., and $R = w$ if $\gamma_{w-2} \leq U$. U is a $j \times 1$ vector of unobservable utility, of, say, a *tuwo* from a pearl millet cultivar, and R_γ is

a vector of preference rankings. The γ 's are threshold variables or cut-off points that provide the ratings of alternatives, S is a matrix of nonstochastic effect-coded variables of N attribute levels for the M products; v is a matrix of marginal values of the g th characteristic level for the j th product; and μ is another matrix of nonstochastic interaction variables of M products and N individuals' characteristics. The interaction terms are effect coded $(-1, 0, 1)$; b is the weight of the interaction term between the g th product's attribute and the i th consumer's characteristics; α is a column vector of constants or the intercept of the equation; and e is the stochastic error term.

The threshold concept is central to the economic theory of consumer behavior (Doyle, 1977). The theory asserts that a buyer responds (buys or rates alternatives) when utility exceeds a threshold or critical level of satisfaction. For example, variations in the independent variable would cause a switch in a consumer's preference ranking when utility reaches some levels. The cut-off points vary with individuals. Individuals with similar tastes and background have similar cut-off points.

The ordered probit analysis of the choice experiment data was supplemented by a classification tree analysis (Breiman et al., 1984). Categorical classification trees are statistical models used to classify categorical data or uncover its predictive structure. An example is predicting a patient's risk for a particular disease based on observed characteristics of the patient. In this application, we are interested in finding the attributes that lead to the strongest preference for millet varieties.

The procedure *rpart* implemented in *S-PLUS* (Venables and Ripley, 1999) was used to estimate the classification tree. This tree-based estimation procedure makes one-step ahead classification splits to minimize the sum of squares from the split. The choice is verified by running a 10-fold cross-validation (Venables and Ripley, 1999, p. 310).

5. Results and discussions

5.1. Ranking and attribute levels

Tables 4–6 present two-way contingency tables of the various sensory attributes and Pearson chi-squared test statistics of the hypothesis of statistical

⁵ Maddala refers to the preference measured on a scale of 1, 2, ..., 5 with 1 being intensely disliked and 5 being intensely liked as an ordered categorical variable (Maddala, 1993).

Table 4
Comparison of the 5 pearl millet cultivars for nonfermented *tuwo* sensory attributes ratings

Attribute	Value	Hainikiré	MTDO92	ZATIB	Souna III	CTO-V	Pearson χ^2	Degrees of freedom	P-value
Color	0	6	11	60	40	50	96.52	4	0.000
	1	108	103	54	74	64			
Appearance (interior)	0	9	18	45	28	43	45.42	4	0.000
	1	105	96	69	86	71			
Aroma	0	9	22	53	28	35	48.64	4	0.000
	1	105	92	61	86	79			
Cohesiveness	0	31	36	11	17	33	69.67	8	0.000
	1	63	55	35	49	51			
	2	20	23	68	48	30			
Firmness	0	12	28	41	26	42	27.66	4	0.000
	1	102	86	73	88	72			
Stickiness	0	39	27	38	43	22	16.60	8	0.035
	1	43	49	34	41	50			
	2	32	38	42	30	42			
Taste	0	17	19	36	22	34	15.58	4	0.004
	1	97	95	78	92	80			
Chewiness	0	12	18	34	22	34	20.27	4	0.000
	1	102	96	80	92	80			
Mouth feel	0	37	44	61	44	49	26.55	8	0.001
	1	32	23	34	39	26			
	2	45	47	19	31	39			
Texture	0	11	19	30	20	35	19.72	4	0.001
	1	103	95	84	94	79			
Rank (%)	1	11	15	40	4	44	179.21	16	0.000
		(9.7)	(13.2)	(35.1)	(3.5)	(38.6)			
	2	9	14	26	46	19			
		(7.9)	(12.3)	(22.8)	(40.4)	(16.7)			
	3	15	14	21	34	30			
	(13.2)	(12.3)	(18.4)	(29.8)	(26.3)				
	4	38	36	21	12	7			
		(33.3)	(31.6)	(18.4)	(10.5)	(6.1)			
	5	41	35	6	18	14			
		(36.0)	(30.7)	(5.3)	(15.8)	(12.3)			
	Total	114	114	114	114	114			
		(100.0)	(100.0)	(100.0)	(100.0)	(100.0)			

Color: (0 = dislike, 1 = liked); Appearance: (0 = dislike, 1 = liked); Aroma: (0 = dislike, 1 = liked); Cohesiveness: (0 = soft, 1 = average, 2 = hard); Firmness: (0 = dislike, 1 = liked); Stickiness: (0 = not sticky, 1 = average, 2 = sticky); Taste: (0 = dislike, 1 = liked); Chewiness: (0 = dislike, 1 = liked); Mouth feel: (0 = slow, 1 = just right, 2 = fast); Texture: (0 = dislike, 1 = liked).

independence (Agresti, 1990) for nonfermented *tuwo*, fermented *tuwo*, and *couscous*, respectively. The results indicate that the panellists were able to discriminate between samples of the same product for each of the attributes and for their overall acceptability. For nonfermented *tuwo*, all attributes are perceived to be significantly different across varieties according to the Pearson chi-squared statistic, with *Hainikiré* showing the highest frequency of preferred attributes and *Zatib* the lowest (Table 4). *Hainikiré* and *MTDO92* had the

best overall rankings, while *Zatib* had the lowest. Similar patterns were found for fermented *tuwo* and *couscous* in Tables 5 and 6, respectively. The only attribute preference that is not significantly different across varieties is the mouth feel of fermented *tuwo*. For all three products *Hainikiré* and *MTDO92* received the highest ranking and *Zatib* received the lowest. The Pearson statistics show that all of the attributes other than the mouth feel of fermented *tuwo* are strongly distinguished. This is evidence that the survey instrument

Table 5
Comparison of the 5 pearl millet cultivars for fermented *tuwo* sensory attributes ratings

Attribute	Value	Hainikiré	MTDO92	ZATIB	Souna III	CTO-V	Pearson χ^2	Degrees of freedom	P-value																																																																																																																																																																																																																																												
Color	0	4	9	60	26	34	106.77	4	0.000																																																																																																																																																																																																																																												
	1	85	80	29	63	55				Appearance (interior)	0	1	8	43	24	20	69.52	4	0.000	1	88	81	46	65	69	Aroma	0	3	8	47	25	20	74.86	4	0.000	1	86	81	42	64	69	Cohesiveness	0	12	17	33	11	17	33.21	8	0.000	1	55	38	26	41	36	2	22	34	30	37	36	Firmness	0	3	15	37	27	25	41.05	4	0.000	1	86	74	52	62	64	Stickiness	0	31	24	20	34	26	22.34	8	0.0004	1	37	33	22	32	33	2	21	32	47	23	30	Taste	0	5	9	41	20	20	52.33	4	0.000	1	84	80	48	69	69	Chewiness	0	6	13	42	19	24	46.60	4	0.000	Mouth feel	0	32	33	49	37	38	10.45	8	0.235	1	30	23	18	22	24	2	27	33	22	30	27	Texture	0	8	9	41	21	23	45.48	4	0.000	1	81	80	48	68	66	Rank (%)	1	4	5	45	13	22	228.43	16	0.000		(4.5)	(5.6)	(50.6)	(14.6)	(24.7)	2	3	7	17	38	24		(3.4)	(7.9)	(19.1)	(42.7)	(27.0)	3	12	10	20	23	24		(13.5)	(11.2)	(22.5)	(25.8)	(27.0)	4	28	33	5	10	13		(31.5)	(37.1)	(5.6)	(11.2)	(14.6)		42	34	2	5	6		(47.2)	(38.2)	(2.23)	(5.6)	(6.7)	Total	89	89	89	89	89						(100.0)	(100.0)	(100.0)	(100.0)	(100.0)
Appearance (interior)	0	1	8	43	24	20	69.52	4	0.000																																																																																																																																																																																																																																												
	1	88	81	46	65	69				Aroma	0	3	8	47	25	20	74.86	4	0.000	1	86	81	42	64	69	Cohesiveness	0	12	17	33	11	17	33.21	8	0.000	1	55	38	26	41	36		2	22	34	30	37	36				Firmness	0	3	15	37	27	25	41.05	4	0.000	1	86	74	52	62	64	Stickiness	0	31	24	20	34	26	22.34	8	0.0004	1	37		33	22	32	33	2	21				32	47	23	30	Taste	0	5	9	41	20	20	52.33	4	0.000	1	84	80	48	69	69	Chewiness	0	6	13	42	19	24	46.60	4	0.000	Mouth feel	0	32	33	49	37	38	10.45		8	0.235	1	30	23	18				22	24	2	27	33	22	30	27	Texture	0	8	9	41	21	23	45.48	4	0.000	1	81	80	48	68	66	Rank (%)	1	4	5		45	13	22	228.43	16	0.000					(4.5)	(5.6)	(50.6)	(14.6)	(24.7)	2	3	7	17	38	24		(3.4)	(7.9)	(19.1)	(42.7)	(27.0)	3	12	10	20	23	24		(13.5)	(11.2)	(22.5)	(25.8)	(27.0)	4	28	33	5	10	13		(31.5)	(37.1)	(5.6)	(11.2)	(14.6)		42	34	2	5	6		(47.2)	(38.2)	(2.23)	(5.6)	(6.7)	Total	89	89	89	89	89						(100.0)	(100.0)	(100.0)	(100.0)	(100.0)
Aroma	0	3	8	47	25	20	74.86	4	0.000																																																																																																																																																																																																																																												
	1	86	81	42	64	69				Cohesiveness	0	12	17	33	11	17	33.21	8	0.000	1	55	38	26	41	36		2	22	34	30	37	36				Firmness	0	3	15	37	27	25	41.05	4	0.000	1	86	74	52	62	64	Stickiness	0	31	24	20	34	26	22.34	8	0.0004	1	37	33	22	32	33		2	21	32	47	23	30				Taste	0	5	9	41	20	20	52.33	4	0.000	1	84	80	48	69	69	Chewiness	0	6	13	42	19	24	46.60	4	0.000	Mouth feel	0	32	33	49	37	38	10.45	8	0.235	1	30	23	18	22	24		2	27	33	22	30	27		Texture			0	8	9	41	21	23	45.48	4	0.000	1	81	80	48	68	66	Rank (%)	1	4	5	45	13	22	228.43	16	0.000		(4.5)	(5.6)	(50.6)	(14.6)	(24.7)		2	3	7		17	38	24								(3.4)	(7.9)	(19.1)	(42.7)	(27.0)	3	12	10	20	23	24		(13.5)	(11.2)	(22.5)	(25.8)	(27.0)	4	28	33	5	10	13		(31.5)	(37.1)	(5.6)	(11.2)	(14.6)		42	34	2	5	6		(47.2)	(38.2)	(2.23)	(5.6)	(6.7)	Total	89	89	89	89	89						(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)											
Cohesiveness	0	12	17	33	11	17	33.21	8	0.000																																																																																																																																																																																																																																												
	1	55	38	26	41	36																																																																																																																																																																																																																																															
	2	22	34	30	37	36				Firmness	0	3	15	37	27	25	41.05	4	0.000	1	86	74	52	62	64	Stickiness	0	31	24	20	34	26	22.34	8	0.0004	1	37	33	22	32	33	2	21	32	47	23	30	Taste	0	5	9	41	20	20	52.33	4	0.000	1	84	80	48	69	69	Chewiness	0	6	13	42	19	24	46.60	4	0.000	Mouth feel	0	32	33	49	37	38	10.45	8	0.235	1	30	23	18	22	24	2	27	33	22	30	27	Texture	0	8	9	41	21	23	45.48	4	0.000	1	81	80	48	68	66	Rank (%)	1	4	5	45	13	22	228.43	16	0.000		(4.5)	(5.6)	(50.6)	(14.6)	(24.7)	2	3	7	17	38	24		(3.4)	(7.9)	(19.1)	(42.7)	(27.0)	3	12	10	20	23	24			(13.5)	(11.2)	(22.5)	(25.8)	(27.0)				4	28	33	5	10	13			(31.5)	(37.1)	(5.6)	(11.2)	(14.6)					42	34	2	5	6		(47.2)	(38.2)	(2.23)	(5.6)	(6.7)	Total	89	89	89	89	89						(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)																																													
Firmness	0	3	15	37	27	25	41.05	4	0.000																																																																																																																																																																																																																																												
	1	86	74	52	62	64				Stickiness	0	31	24	20	34	26	22.34	8	0.0004	1	37	33	22	32	33		2	21	32	47	23	30				Taste	0	5	9	41	20	20	52.33	4	0.000	1	84	80	48	69	69	Chewiness	0	6	13	42	19	24	46.60	4	0.000	Mouth feel	0	32	33	49	37	38	10.45	8	0.235	1	30		23	18	22	24	2	27				33	22	30	27	Texture	0	8	9	41	21	23	45.48	4	0.000	1	81	80	48	68	66	Rank (%)	1	4	5	45	13	22	228.43		16	0.000		(4.5)	(5.6)	(50.6)				(14.6)	(24.7)	2	3	7	17	38	24		(3.4)	(7.9)	(19.1)	(42.7)	(27.0)	3	12	10	20	23	24		(13.5)	(11.2)	(22.5)		(25.8)	(27.0)	4	28	33	5				10	13		(31.5)	(37.1)	(5.6)	(11.2)	(14.6)		42	34	2	5	6		(47.2)	(38.2)	(2.23)	(5.6)	(6.7)	Total	89	89	89	89	89						(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)																																																					
Stickiness	0	31	24	20	34	26	22.34	8	0.0004																																																																																																																																																																																																																																												
	1	37	33	22	32	33																																																																																																																																																																																																																																															
	2	21	32	47	23	30				Taste	0	5	9	41	20	20	52.33	4	0.000	1	84	80	48	69	69	Chewiness	0	6	13	42	19	24	46.60	4	0.000	Mouth feel	0	32	33	49	37	38	10.45	8	0.235	1	30	23	18	22	24	2	27	33	22	30	27	Texture	0	8	9	41	21	23	45.48	4	0.000	1	81	80	48	68	66	Rank (%)	1	4	5	45	13	22	228.43	16	0.000		(4.5)	(5.6)	(50.6)	(14.6)	(24.7)	2	3	7	17	38	24		(3.4)	(7.9)	(19.1)	(42.7)	(27.0)	3	12		10	20	23	24		(13.5)					(11.2)	(22.5)	(25.8)	(27.0)				4	28	33	5	10	13		(31.5)	(37.1)	(5.6)	(11.2)	(14.6)		42	34	2	5	6		(47.2)	(38.2)	(2.23)	(5.6)	(6.7)	Total	89	89	89	89	89						(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)																																																																																			
Taste	0	5	9	41	20	20	52.33	4	0.000																																																																																																																																																																																																																																												
	1	84	80	48	69	69				Chewiness	0	6	13	42	19	24	46.60	4	0.000	Mouth feel	0	32	33	49	37	38	10.45	8	0.235	1	30	23	18	22	24		2	27	33	22	30	27				Texture	0	8	9	41	21	23	45.48	4	0.000	1	81	80	48	68	66	Rank (%)	1	4	5	45	13	22	228.43	16	0.000		(4.5)		(5.6)	(50.6)	(14.6)	(24.7)	2	3				7	17	38	24		(3.4)	(7.9)	(19.1)	(42.7)	(27.0)	3	12	10	20	23	24		(13.5)	(11.2)	(22.5)		(25.8)	(27.0)	4	28	33	5		10			13		(31.5)	(37.1)	(5.6)	(11.2)	(14.6)		42	34	2	5	6		(47.2)	(38.2)	(2.23)	(5.6)	(6.7)	Total	89	89	89	89	89						(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)																																																																																															
Chewiness	0	6	13	42	19	24	46.60	4	0.000																																																																																																																																																																																																																																												
Mouth feel	0	32	33	49	37	38	10.45	8	0.235																																																																																																																																																																																																																																												
	1	30	23	18	22	24																																																																																																																																																																																																																																															
	2	27	33	22	30	27				Texture	0	8	9	41	21	23	45.48	4	0.000	1	81	80	48	68	66	Rank (%)	1	4	5	45	13	22	228.43	16	0.000		(4.5)	(5.6)	(50.6)	(14.6)	(24.7)	2	3	7	17	38	24		(3.4)	(7.9)	(19.1)	(42.7)	(27.0)	3	12	10	20	23	24		(13.5)		(11.2)	(22.5)	(25.8)	(27.0)	4	28				33	5		10	13		(31.5)	(37.1)	(5.6)				(11.2)	(14.6)		42	34	2	5	6		(47.2)	(38.2)	(2.23)	(5.6)	(6.7)	Total	89	89	89	89	89						(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)																																																																																																																																			
Texture	0	8	9	41	21	23	45.48	4	0.000																																																																																																																																																																																																																																												
	1	81	80	48	68	66				Rank (%)	1	4	5	45	13	22	228.43	16	0.000		(4.5)	(5.6)	(50.6)	(14.6)	(24.7)		2	3	7	17	38	24					(3.4)	(7.9)	(19.1)	(42.7)	(27.0)	3	12	10	20	23	24		(13.5)	(11.2)	(22.5)	(25.8)	(27.0)	4	28	33	5	10	13		(31.5)		(37.1)	(5.6)	(11.2)	(14.6)		42				34	2	5	6		(47.2)	(38.2)	(2.23)	(5.6)	(6.7)	Total	89	89	89	89	89						(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)																																																																																																																																																			
Rank (%)	1	4	5	45	13	22	228.43	16	0.000																																																																																																																																																																																																																																												
		(4.5)	(5.6)	(50.6)	(14.6)	(24.7)																																																																																																																																																																																																																																															
	2	3	7	17	38	24																																																																																																																																																																																																																																															
		(3.4)	(7.9)	(19.1)	(42.7)	(27.0)																																																																																																																																																																																																																																															
	3	12	10	20	23	24																																																																																																																																																																																																																																															
		(13.5)	(11.2)	(22.5)	(25.8)	(27.0)																																																																																																																																																																																																																																															
	4	28	33	5	10	13																																																																																																																																																																																																																																															
	(31.5)	(37.1)	(5.6)	(11.2)	(14.6)																																																																																																																																																																																																																																																
	42	34	2	5	6																																																																																																																																																																																																																																																
	(47.2)	(38.2)	(2.23)	(5.6)	(6.7)																																																																																																																																																																																																																																																
Total	89	89	89	89	89																																																																																																																																																																																																																																																
	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)																																																																																																																																																																																																																																															

Color: (0 = dislike, 1 = liked); Appearance: (0 = dislike, 1 = liked); Aroma: (0 = dislike, 1 = liked); Cohesiveness: (0 = soft, 1 = average, 2 = hard); Firmness: (0 = dislike, 1 = liked); Stickiness: (0 = not sticky, 1 = average, 2 = sticky); Taste: (0 = dislike, 1 = liked); Chewiness: (0 = dislike, 1 = liked); Mouth feel: (0 = slow, 1 = just right, 2 = fast); Texture: (0 = dislike, 1 = liked).

did identify sensory attributes that the members of the households were able to distinguish. These results are consistent with findings on sorghum *tuwo* quality evaluation in Niger in which appearance and color showed the most discrimination (Aboubakar, 1992).

One-way ANOVA was used to assess differences in traits' ratings based on socioeconomic variables such as gender, ethnic group, level of education, age groups, household size, and daily consumption frequency of *tuwo* or *couscous*. The results indicated that

consumers' ratings of all traits did not differ by gender, level of education, age, household size, or daily consumption frequency of *tuwo* or *couscous*. However, consumers' rating of traits (except for color) significantly differed by ethnic group. Therefore, further analysis included ethnic group as the socioeconomic variable. This was implemented by introducing interactions between attributes and a dummy variable with a value of 0 for the Zarma ethnic group and a value of 1 for the Haoussa ethnic group.

Table 6
Comparison of the 5 pearl millet cultivars for *couscous* sensory attributes rating

Attribute	Value	Hainikiré	MTDO92	ZATIB	Souna III	CTO-V	Pearson χ^2	Degrees of freedom	P-value																																																																																																																																																																																										
Color	0	5	3	53	47	22	107.42	4	0.000																																																																																																																																																																																										
	1	109	111	61	67	92				Aroma	0	12	12	49	42	24	55.41	4	0.000	1	102	102	65	72	90	Cohesiveness	0	33	74	35	23	20	103.33	8	0.000	1	66	30	46	42	53	2	15	10	33	49	41	Stickiness	0	64	30	44	43	54	45.23	8	0.000	1	40	41	47	52	45	2	10	43	23	19	15	Taste	0	12	5	44	39	21	57.42	4	0.000	1	102	108	70	75	93	Chewiness	0	12	5	41	43	24	58.92	4	0.000	1	102	109	73	71	90	Texture	0	16	9	35	32	26	25.50	4	0.000	1	98	105	79	82	88	Rank	1	5	11	44	34	20	151.84	16	0.000		(4.4)	(9.7)	(38.6)	(29.9)	(17.5)	2	11	9	26	35	33		(9.7)	(7.9)	(22.8)	(30.7)	(29.0)	3	24	15	24	21	30		(21.1)	(13.2)	(21.1)	(18.4)	(26.3)	4	41	41	11	8	13		(36.0)	(36.0)	(9.7)	(7.0)	(11.4)	5	33	38	9	16	18		(29.0)	(33.3)	(7.9)	(14.0)	(15.8)	Total	114	114	114	114	114					(100.0)	(100.0)	(100.0)	(100.0)
Aroma	0	12	12	49	42	24	55.41	4	0.000																																																																																																																																																																																										
	1	102	102	65	72	90				Cohesiveness	0	33	74	35	23	20	103.33	8	0.000	1	66	30	46	42	53		2	15	10	33	49	41				Stickiness	0	64	30	44	43	54	45.23	8	0.000	1	40		41	47	52	45	2	10				43	23	19	15	Taste	0	12	5	44	39	21	57.42	4	0.000	1	102	108	70	75	93	Chewiness	0	12	5	41	43	24	58.92	4	0.000	1	102	109	73	71	90	Texture	0	16	9	35	32	26	25.50	4	0.000	1	98	105	79	82	88	Rank	1	5	11	44	34	20	151.84		16	0.000		(4.4)	(9.7)	(38.6)				(29.9)	(17.5)	2	11	9	26	35	33		(9.7)	(7.9)	(22.8)	(30.7)	(29.0)	3	24	15	24	21	30		(21.1)	(13.2)	(21.1)	(18.4)	(26.3)	4	41	41	11	8	13		(36.0)	(36.0)	(9.7)	(7.0)	(11.4)	5	33	38	9	16	18		(29.0)	(33.3)	(7.9)	(14.0)	(15.8)	Total	114	114	114	114	114					(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)		
Cohesiveness	0	33	74	35	23	20	103.33	8	0.000																																																																																																																																																																																										
	1	66	30	46	42	53																																																																																																																																																																																													
	2	15	10	33	49	41																																																																																																																																																																																													
Stickiness	0	64	30	44	43	54	45.23	8	0.000																																																																																																																																																																																										
	1	40	41	47	52	45																																																																																																																																																																																													
	2	10	43	23	19	15																																																																																																																																																																																													
Taste	0	12	5	44	39	21	57.42	4	0.000																																																																																																																																																																																										
	1	102	108	70	75	93				Chewiness	0	12	5	41	43	24	58.92	4	0.000	1	102	109	73	71	90	Texture	0	16	9	35	32	26	25.50	4	0.000	1	98	105	79	82	88	Rank	1	5	11	44	34	20	151.84	16	0.000		(4.4)	(9.7)	(38.6)	(29.9)	(17.5)	2	11	9	26	35	33		(9.7)	(7.9)	(22.8)	(30.7)	(29.0)	3	24	15	24	21	30		(21.1)	(13.2)	(21.1)	(18.4)	(26.3)	4	41	41	11	8	13		(36.0)	(36.0)	(9.7)	(7.0)	(11.4)	5	33	38	9	16	18		(29.0)	(33.3)	(7.9)	(14.0)	(15.8)	Total	114	114	114		114	114						(100.0)			(100.0)	(100.0)	(100.0)	(100.0)	(100.0)																																																																						
Chewiness	0	12	5	41	43	24	58.92	4	0.000																																																																																																																																																																																										
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Color: (0 = dislike, 1 = liked); Aroma: (0 = dislike, 1 = liked); Cohesiveness: (0 = soft, 1 = average, 2 = hard); Stickiness: (0 = not sticky, 1 = average, 2 = sticky); Taste: (0 = dislike, 1 = liked); Chewiness: (0 = dislike, 1 = liked); Texture: (0 = dislike, 1 = liked).

5.2. Ordered probit model results

Separate models were estimated for *couscous*, fermented *tuwo*, and nonfermented *tuwo* using ordered probit. All explanatory variables are noncontinuous and entered as effect-coded variables (for example, taking the values of $[-1, 1]$ rather than a series of 0–1 dummy variables). The use of effect coding instead of dummy variables leads to marginal effect coefficients equal to partworths (Hamath et al., 1997). Results of the ordered probit models, major statistical properties, and specification test results are reported in Table 7. The interaction effects that were introduced to capture preference differences across ethnic groups are reported in Table 8. According to Maddala, the threshold coefficients or γ_i 's should exhibit the following relationship $\gamma_1 \leq \gamma_2 \leq \dots \leq \gamma_{w-2}$, and must be

positive. Failure to exhibit any of these conditions would imply a specification error of the model. All threshold coefficients were positive and statistically significant at the 95% confidence interval (Table 7) implying that there is no specification error.

A second test was done to look at the overall significance of the independent variables (levels of product attributes and consumer profile) in explaining the variation in the dependent variable rankings. A log-likelihood test distributed as $F_{551,5}$ with a critical value of 10.12 indicated strong rejection of the null hypothesis of the test, $\nu = b = 0$ at the 95% confidence interval for all three food products. The p -values are 0 to 3 or more significant digits in all three cases. This means that the product attributes and consumer profile variables are relevant in explaining variation in consumer preferences.

Table 7
Main effects estimates: Effects of product attributes on rankings and major statistical properties of the ordered probit models

Product Variables	Fermented <i>tuwo</i>	Nonfermented <i>tuwo</i>	<i>Couscous</i>
Constant	0.250	0.239	0.691
Color	0.053	0.328**	0.259***
Aroma	−0.007	−0.152	0.092
Cohesiveness (hard at touch)	0.109	0.171*	−0.156***
Stickiness	−0.283**	−0.008	−0.090
Taste	0.335*	0.535**	0.311***
Chewiness	0.313**	−0.042	0.310***
Appearance (interior)	0.096	0.258	
Consistency	0.275*	0.252**	
Mouth feel	0.169*	0.119	
Coefficient of the threshold variables			
γ_1	0.754***	0.823***	0.790***
γ_2	1.391***	1.505***	1.432***
γ_3	2.098***	2.213***	2.214***
Log-likelihood	−631.926	−749.380	−760.941
Restricted log-likelihood (slopes = 0)	−716.200	−869.097	−869.097
Chi-squared (18-18-12)	168.548	239.433	216.311
Significance level	0.000	0.000	0.000
Degree of freedom	426	551	551

*Denotes significance at the 10% level, ** at the 5% level, and *** at the 1% level.

Lastly, the estimated coefficients listed in Table 7 were tested using a *t*-test. For nonfermented *tuwo*, color, cohesiveness, taste, consistency coefficients were found to be statistically significant at least at the 10% level. Stickiness, taste, chewiness, consistency, and mouth feel coefficients were significant at least at the 10% level for fermented *tuwo*. All *couscous* attributes except for aroma and stickiness were significant at the 1% level. The nonsignificance of a coefficient does not mean that the attribute or the level of the attribute is not important to consumers. Rather, it implies that consumers are indifferent to the proposed range of variation in the level of attributes.

5.3. Partworth estimates

The strength-of-choice experiment analysis is to decompose the revealed preference, i.e., rankings, of all individuals into marginal values or partworth estimates. Table 7 contains the main effect coefficients of product attributes that represent marginal values or partworths that a “typical” consumer, irrespective of background, places on attributes of *couscous*, fermented *tuwo*, or nonfermented *tuwo*. To illustrate, the color of a nonfermented *tuwo* product has a marginal

value of 0.328 to an average consumer. Similarly, the taste of a fermented *tuwo* has a marginal value of 0.335 to an average consumer. Negative partworths mean that consumers’ preference would decrease when attribute levels are increased. For example, for a typical fermented *tuwo* consumer, stickiness has a negative marginal value (−0.283). Since utility or preference is an ordinal measure, the relative importance of those coefficients is more important than absolute magnitude.

Table 8 contains the estimated coefficients of interaction terms between the Haoussa ethnic group dummy variable and product characteristics. They represent the incremental value of preferences for products by members of the Haoussa ethnic group. For example, a typical Haoussa would value more the consistency of fermented *tuwo*, the cohesiveness of nonfermented *tuwo*, and the stickiness of *couscous* compared with the average Zarma consumer.

5.4. Categorical classification tree results

The categorical classification trees for the three final products are presented in Figs. 1–3. The variable that is being explained in the trees is the overall ranking of varieties, which ranges from 1 to 5. Each node in the

Table 8
Selected interaction effects of Haoussa ethnic dummy and product attributes

Variables	Fermented <i>tuwo</i>	Nonfermented <i>tuwo</i>	<i>Couscous</i>
Color	-0.237	0.128	-0.231
Aroma	-0.137	-0.249	0.048
Cohesiveness (hard at touch)	0.068	0.212*	-0.015
Stickiness	-0.058	0.022	0.331*
Taste	0.018	0.120	-0.242
Chewiness	0.125	-0.166	0.123
Appearance	-0.041	0.05	
Consistency	0.274*	0.155	
Mouth feel	0.133	0.060	

*Denotes significance at the 10% level, ** at the 5% level, and *** at the 1% level.

trees contains the number of correct classifications of each preference value. For example, in the couscous classification tree in Fig. 1 the tree starts at the node with 114 observations on each of the preference values from 1 to 5, representing the complete sample. Then when taste is used to split the sample and the taste is preferred (taste = 1), the highest preference (5) is

explained for 111 of the 114 observations. The branches of the tree are the attributes that are used to split the data. So, in the case of couscous taste, color, and chewiness explain the highest preference, and 106 out of 114 observations are correctly classified (bottom right in Fig. 1). This result is consistent with the ordered probit results that taste, color, and chewiness have the significant positive marginal values.

Fig. 2 presents the fermented *tuwo* classification tree. This figure reveals that taste, aroma, and consistency explain the highest preference for millet varieties. In this case the classification tree analysis adds significant information to the probit results because there is one significant difference between the classification tree results and the ordered probit results. The aroma of fermented *tuwo* has a statistically insignificant negative marginal value in the ordered probit analysis, but it correctly classifies 84 out of 89 of the highest preferences. The insignificant ordered probit coefficient is likely caused by inadequate variation in aroma preferences across the five levels of preference variety. In other words, most respondents found the aroma of fermented *tuwo* from the bottom four varieties to be about the same. Nevertheless, the aroma of

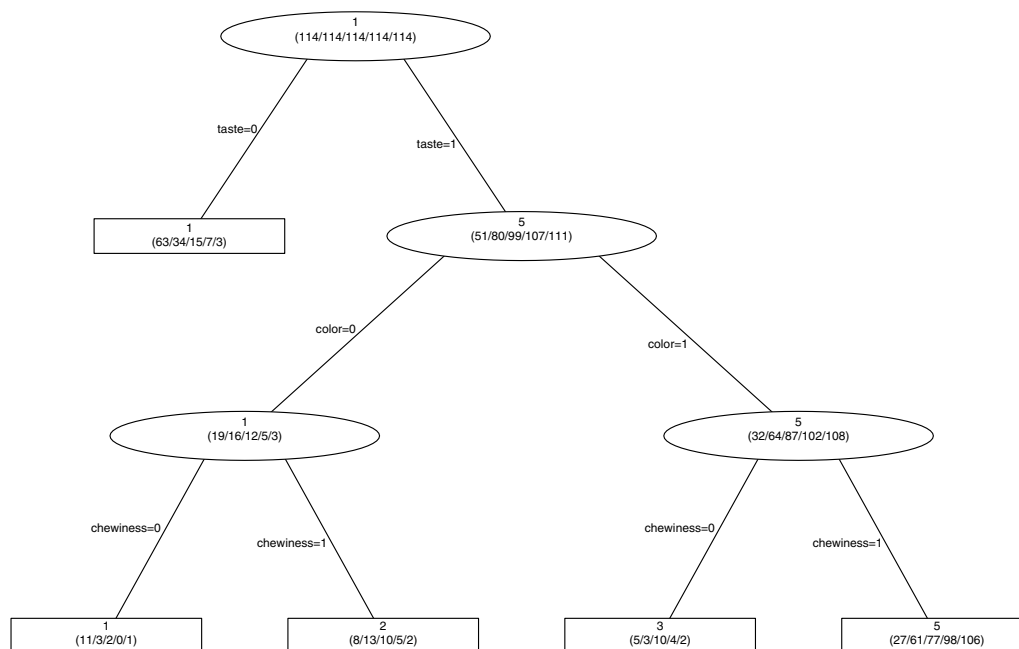


Fig. 1. Couscous classification tree.

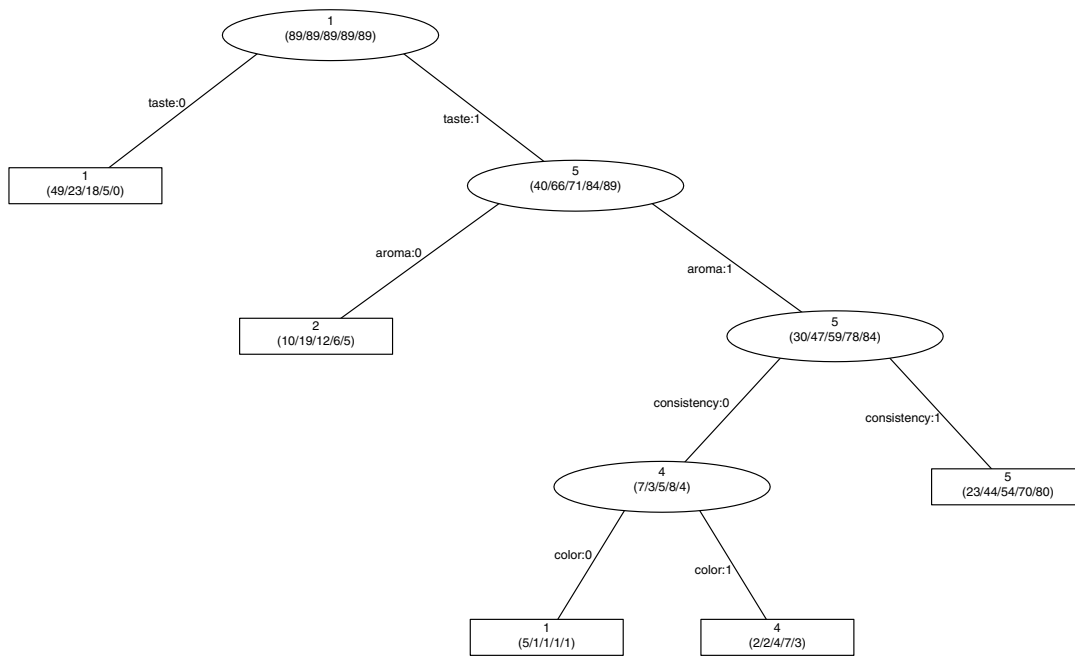


Fig. 2. Fermented *towu* classification tree.

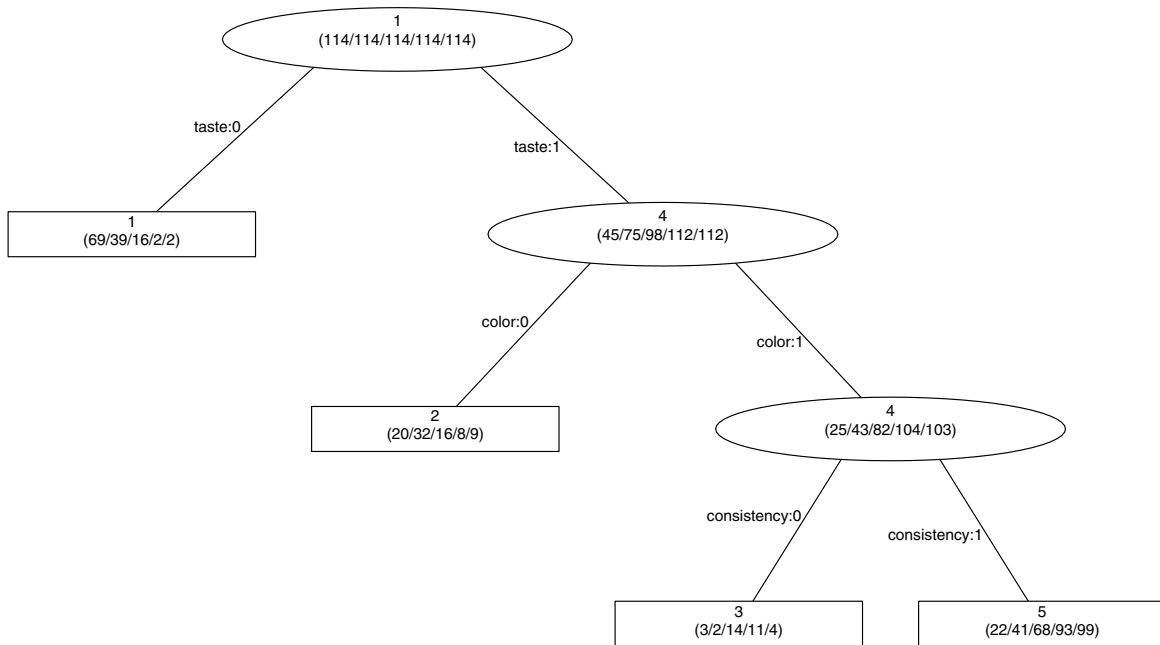


Fig. 3. *Towu* classification tree.

the most preferred variety clearly distinguishes that variety from the other four. In addition, chewiness, which has a statistically significant marginal value of 0.313, does not appear in the classification tree. This means that chewiness does not do a good job of discriminating between highest preference and lowest preference.

The classification tree results for *tuwo*, presented in Fig. 3, are very consistent with the ordered probit results. Taste, color, and consistency explain the highest preference for *tuwo*, with 99 out of 114 observations being correctly classified. These are the three variables with large, positive, and statistically significant coefficients in the ordered probit model. Thus these three attributes have large marginal values in *tuwo* consumption and explain the highest variety preference.

5.5. Attribute value and relative importance of product attributes

Partworth values are commonly utilized in choice experiment analysis. A large partworth value associated with an attribute level indicates high preferences for that particular level. These results are consistent with prior sorghum sensory studies. The criteria for a good sorghum *tuwo* found in Mali were the taste, color, texture, and keeping quality (Scheuring et al., 1982). In Burkina Faso and Mali, a good *tuwo* is one with a firm paste that holds together and does not crumble under finger pressure. Firmness and nonstickiness must remain constant when *tuwo* is stored overnight before consumption. Yellow or white *tuwo* is preferred, while pink, red, or gray *tuwo* may be rejected (Da et al., 1982). Similarly, in East and Southern Africa, desirable texture and keeping quality of light-colored *ugali* are the most important traits (Mukuru et al., 1982). Light-colored, white-cream, or yellowish-colored with good keeping quality are preferred by *tuwo* consumers in Nigeria. In Niger, stickiness of the *tuwo* in the mouth and cohesiveness were the most important traits. Taste and aroma were also proven to be important. Color, taste, and texture were found to be the most important traits preferred by *couscous* consumers in Niger (Oumarou et al., 1998).

Findings from this study indicate that taste, chewiness, color, and cohesiveness are the most important attributes preferred by *couscous* consumers. In effect, light, white creamed, or yellowish colors were found to be the most preferred color. These colors are similar

to *couscous*, made of wheat, found in the market. Dark colors were found to be the least preferred. For non-fermented *tuwo* consumers, color, cohesiveness, taste, and consistency were the most important traits. Finally, stickiness, taste, chewiness, consistency, and mouth feel were found to be the most important fermented *tuwo* traits. Color was not found to be an important trait for fermented *tuwo*. In effect, fermentation may improve *tuwo* color if grains are soaked in an acid environment, as the pH level plays an important role in determining color. Acid *tuwo* color is always lighter than alkali *tuwo* (Scheuring et al., 1982). In this study, fermentation of grains may have improved the color of the *tuwo*. Thus, consumers may have been unable to discern the color of the fermented *tuwo*. Keeping quality was found to be an important trait in many studies. However, in this study, significant and positive association were found between the ranking before and after overnight suggesting that for the varieties tested, keeping quality was consistent across varieties. In effect, varieties that were poorly rated the first day were also poorly rated the next. In effect, every time a *tuwo* has poor texture, it also has poor keeping quality. No exception was found to that rule (Scheuring et al., 1982).

In order of increasing importance, taste, color, texture, and keeping quality were the most important traits (Scheuring et al. 1982). Similarly, stickiness and cohesiveness (which are textural traits), taste, and aroma were also found to be the most important traits by order of importance in Niger (Aboubakar, 1992). The relative importance of product traits differs in this study. In effect, for nonfermented *tuwo* consumers; taste, color, consistency, and cohesiveness are the important traits by order of importance. The discrepancies from prior evaluation studies may be explained by the failure to account for multiple correlations that exist between traits. Most previous studies used simple correlation or single regression models to derive the relative importance of traits to consumers.

Table 9 shows the relative importance of traits for the three products to consumers. It is computed by taking the difference between the highest and the lowest partworth value of an attribute over the sum of the ranges for all attributes. Relative importance allows an attribute-to-attribute comparison. It indicates which attributes produce more value. For *couscous*, the taste and chewiness are the most important attributes followed by color and cohesiveness. For nonfermented

Table 9
Relative importance of product attributes (%)

Product attributes	Fermented <i>tuwo</i>	Nonfermented <i>tuwo</i>	<i>Couscous</i>
Color	0	26	25
Aroma	0	0	0
Cohesiveness (hard at touch)	0	13	15
Stickiness	21	0	0
Taste	24	42	30
Chewiness	23	0	30
Appearance (interior)	0	0	
Consistency	20	20	
Mouth feel	12	0	
Total	100	100	100

tuwo, taste, color, consistency, and cohesiveness are of decreasing importance. Finally, for fermented *tuwo*; taste, chewiness, stickiness, and mouth feel are important in decreasing order (Table 9). The results for *couscous* and nonfermented *tuwo* are consistent with the classification tree results, providing strong evidence of the importance of the identified attributes. The results for fermented *tuwo* are not as clear. Again, this may be because the fermentation process masks significant differences between varieties.

Combining these results, a consumption-oriented explanation of preferences for millet varieties would concentrate on the taste, color, and chewiness of *couscous* and the taste, color, and consistency of *tuwo*. These results highlight the importance of good taste and color attributes for household acceptance of millet varieties. Failure to produce light-colored *couscous* and *tuwo* with a taste like that of traditional varieties used in the household would result in household resistance to the adoption of new millet varieties.

6. Summary and conclusion

In order to develop varieties that are acceptable to producers and food processors, breeders must select for desirable traits. The primary objective of this study was to evaluate consumer preference for *couscous* and *tuwo* traits. Choice experiment analysis was used to estimate the marginal value of product attributes. Classification trees were used to identify the attributes that lead to the most preferred variety.

The most important attribute explaining preference is taste. This attribute is difficult to quantify. It refers to having the taste qualities that households prefer. These preferences are reflected in the consumption choices of the household. So, we can conclude that in order to make new varieties acceptable they must be bred to have a taste that is close to the taste of traditional varieties used in the household. To aid this breeding work food chemical analysis of varieties with preferred taste qualities are needed. The second most important attribute is color. Households want *couscous* and *tuwo* to have a light, creamy color. Absence of this color attribute will cause a new variety to be rejected by households. Of lesser importance in determining household acceptance are the chewiness of *couscous* and the consistency of *tuwo*. These taste preferences will play a significant role in household acceptance of new millet varieties and consumer acceptance of processed products from millet. Research is needed to correlate this consumer preference with measurable physical and chemical characteristics of alternative millet varieties.

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