Research Article

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Measuring consumers' interest in instant fortified pearl millet products: a field experiment in Touba, Senegal

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Abstract

BACKGROUND: In Africa, food-processing industries are emerging fast, especially for cereals. New low-cost extrusion cookers give small enterprises an opportunity to enter the market for processed cereal products, in particular instant, fortified and flavoured mixes. Before engaging in the marketing of these products, consumers' interest needs to be assessed. This study used a combination of affective tests and experimental auctions with 200 consumers in Touba, Senegal, to evaluate four new products with conventional pearl millet flour as the control: instant pearl millet flour, instant pearl millet flour with added dry mango and carrot powder (naturally fortified), and the previous products with added conventional chemical micronutrient fortificants.

RESULTS: During affective tests, consumers made little distinction between the five products in appearance, aroma, taste and overall appreciation. The experimental auctions showed that, without providing additional information on the products, there was no difference in 'willingness to pay' (WTP) between them. However, after that information is provided, consumers were willing to pay a modest premium for instant flour, and a large premium for added mango and carrot extract and for added micronutrients, but were not willing to pay a premium if those micronutrients came from natural sources. Income increased overall WTP, while education increased WTP for instant flour.

CONCLUSION: There is a potential market in low-income African countries for instant and fortified cereal food products, but likely in the higher income and education groups. The increased cost needs to be compared to the premiums consumers are willing to pay. In the next step, the new and promising products could be tested in pilot markets, with target consumers.

Keywords: consumers; millet; instant; Africa

INTRODUCTION

Cereals are major food staples in many African countries, where food processing industries are emerging fast.[1] New low-cost extrusion cookers allow small enterprises to enter the market for processed cereal products, including instant, fortified and flavoured mixes. Before engaging in the marketing of these products, however, it is important that consumers' interests and preferences are properly assessed.

The Food Processing and Post-Harvest Handling Innovation Lab (FPL) project, supported by USAID Feed the Future, aims to sustainably reduce post-harvest losses through technologies and innovations that link farmers to markets, with a focus on Kenya and Senegal (https://ag.purdue.edu/ipia/fpl/Pages/default.aspx). To reduce post-harvest losses, the project works with hermetic storage technologies such as the Purdue Improved Cereal Storage (PICS) bags, improved drying methods and low-cost grain moisture meters. To link farmers to markets and increase marketing opportunities, the project aims to increase and diversify food processing markets for cereal and legume products at the rural and urban levels, and to create a sustainable market-driven model for nutritionally enhanced foods.

One of the processing technologies the project is applying and evaluating is high-temperature short-time (HTST) extrusion cooking to produce ready-to-eat (RTE) instant (powder-based) cereal products, fortified with plant food ingredients rich in micronutrients (natural fortificants) as well as synthetic micronutrient fortificants. The HTST extrusion cooking technology has been used extensively in the production of RTE cereal snacks due to its ease of operation and ability to produce a variety of textures and shapes which appeal to consumers.[2] The technology can also be used to develop food products with higher nutritional quality such as breakfast cereals containing soy.[3]

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Purdue University has developed a mini single-screw extrusion extruder, much less expensive than the standard industrial models. It is now commercially available (Technochem International, Inc., Boone, Iowa) with a capacity of 45 kg of grain per hour, suitable for small and medium enterprises in developing countries.

In many developing countries, cereals are the major food staples, in particular rice and pearl millet in Senegal[4] and maize in Kenya.[5] In both countries, project research teams conducted focus group discussions with low- and medium-income women in 2015. The results indicate a strong interest in affordable instant cereal products with improved nutritional qualities. Participants from both groups were interested in instant cereal foods: the poor because it saves energy, the medium-income groups because it saves time (if they cook themselves) and it can easily be done by the home help without much training. In South Africa, low-cost instant sorghum porridge powders have been brought to the market at a cost of approximately US$1.50 for 1 kg, and are very popular.

Before bringing improved cereal food products to the market in low-income countries, it is important to evaluate consumer acceptance of these products. In Africa, HarvestPlus (a program to reduce malnutrition through biofortification of staple food crops) has been conducting consumer acceptance studies for biofortified crops such as orange-fleshed sweet potatoes,[6] while the International Maize and Wheat Improvement Centre (CIMMYT) conducted similar studies with Quality Protein Maize (QPM) in East Africa.[7] HarvestPlus organised the first combination of sensory evaluation with economic experiments, in particular choice experiments, with provitamin A biofortified (proVA) maize[8] and orange-fleshed sweet potatoes.[9] CIMMYT first tried to estimate consumers' willingness to pay (WTP) for proVA maize with the Becker–DeGroot–Maschak (BDM) mechanism (a simulated auction) with proVA maize and found the mechanism convenient for work in rural areas.[10] Further, CIMMYT and its partners expanded this work on consumer acceptance of biofortified food crops, now combining affective tests (with representative consumers) and the BDM mechanism. This combination was used on proVA biofortified maize in Ghana,[11,12] and QPM in Tanzania[11] and Ethiopia.[13]

Unlike these previous studies, the products under study here are processed cereal products. Small and medium enterprises (SMEs) would be interested in producing instant cereal products with improved nutritional quality if they can make profit. Therefore, before producing and marketing these products, consumers' acceptance and their WTP needs to be assessed. In particular, the premium consumers are willing to pay for instant versus regular cereal products, and for fortification with vitamins and minerals needs to be estimated and compared to their respective production cost, and included in the total production cost, with the cost of raw ingredients, packaging, marketing and so forth.

The objective of this study was therefore to (1) assess consumer acceptance of the new, instant cereal products through affective tests; and (2) estimate consumers' WTP for the different product traits tested: instant, added flavour, added micronutrients and added micronutrients from natural sources.

METHODS

Overview

Two methods are commonly used to assess consumers' interest in new food products: affective tests and experimental auctions. Affective tests involve sensory evaluation of the new products by representative consumers, in contrast with trained panels.[14] Experimental auctions are organised to elicit consumers' WTP for the products. More recently, consumer studies have combined the two methods to obtain both consumers' evaluation and WTP. The combination of sensory evaluation with experimental auctions to evaluate consumers' preferences is a common practice in developing countries.

In the USA, several such studies have now been conducted, for example, on different types of meat.[15–17] In Europe, the method is also popular, for example, for studying consumers' interest in food quality such as in specialty foods[18] or organic foods.[15] The sensory evaluation is usually conducted with a nine-point hedonic scale,[19] while the experimental auction is usually a variation of a variation of the Vickrey auction.[20] In a Vickrey auction, the winner is the highest bidder, but he or she only pays the second-highest bid price (or the 5th or *n*-th price in variations), making the auction incentive-compatible.

In Africa, this type of consumer study is fairly recent. Experimental auctions have been used in combination with taste sessions, for example, in East Africa for assessing consumer interest in improved milk quality in Kenya[21] and Ethiopia,[22] and in West Africa for rice with improved quality in Benin[23] and Senegal.[24] However, these studies did not include formal sensory evaluation.

Combinations of formal sensory evaluations with experimental auctions in Africa were first conducted with biofortified crops. The first experiment was with orange maize, biofortified with provitamin A, and combined home use test, choice experiments, and information on health benefits.[8] A similar experiment was conducted in Ghana, now with a central location test and different types of experiments (choice experiment, Vickrey 5th auction and BDM).[12] The experience of this study showed how BDM, which is conducted individually, was easy to use with respondents with little or no education, and particularly suited for rural dispersed populations. It was therefore selected to estimate WTP for quality protein maize, in combination with both central locations affective tests[7] and modified home use tests, with adults[25] and with both mothers and children,[13] with all experiments including an information component.

The current study builds on the experience of consumer experiments in both developed and developing countries that combine sensory evaluation with economic experiments. It used the BDM as this is the most convenient auction mechanism as it is a one-on-one procedure more convenient for consumers with little or no education, in contrast to group auctions. As in previous studies, it uses information as a factor. Unlike the studies in West Africa, it uses formal affective tests so their effect on WTP can be analysed. Further, this is the first time the method has been applied to test processed food products in Africa, and to measure consumers' WTP for specific traits, in particular instant products.

In this study, 200 consumers, men and women 18 years or older, from Touba, a regional capital in central Senegal, tasted and evaluated porridge from instant and fortified pearl millet flour, produced using a mini-extrusion cooker, in comparison to plain traditional pearl millet, for the major sensory attributes: appearance, aroma, taste and overall appreciation. The major product traits under evaluation were instant versus regular cooking, added flavour, nutritional supplements, and natural versus synthetic supplements.

Participants received a show-up fee, after which they were asked some socio-economic questions, followed by affective tests with cooked products to determine their acceptance, and an economic experiment to determine their WTP for the packed finished products (flours), conducted either with or without information on the content of the products (Fig. 1).

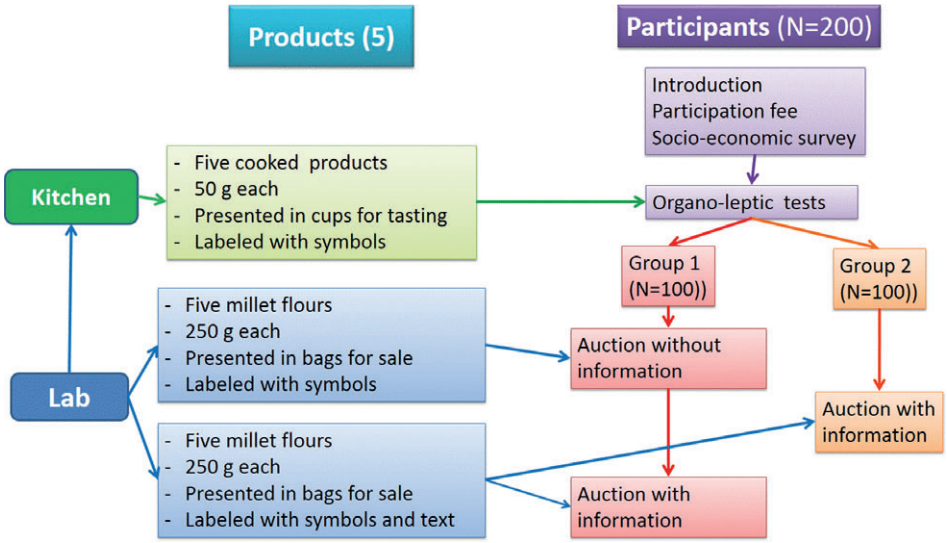

Figure 1. Study design.

The products

To attain the research objectives, the product traits of interest (instant, added flavour, added micronutrients and added micronutrients from natural sources) were carefully distributed over five different products, all made from pearl millet, a major cereal in Senegal (Fig. 2). The following products were included: (A) traditional pearl millet flour (MF), decorticated; (B) instant decorticated MF; (C) instant decorticated MF, flavoured with mango and carrot extract; (D) instant decorticated MF, flavoured with mango and carrot extract, and fortified with micronutrients (iron); (E) instant decorticated MF, flavoured with dried mango and carrot powders, and fortified with a natural product, hibiscus, which also added a distinct red colour and specific flavour. The detailed composition is presented in Table 1. Because the powdered dried mango naturally contained sugar and because the traditional pearl millet porridge is normally sweetened by consumers, the sugar content of all products was uniformly adjusted to 100 g kg^{-1} (dry basis), the same level as contributed by the mango powder.

Selection of site and participants

The city of Touba was selected because it is representative of medium-size cities in predominantly rural areas targeted by the project to test new approaches in food processing. In collaboration with Purdue University and the Institut de Technologie Alimentaire (ITA), SMEs in Touba have been successful in developing and marketing new food products. For this study, a two-stage random-sampling design was used. A list of the suburbs around Touba was obtained from the Mayor of Touba's office, and five were drawn randomly. In each selected suburb, a list of all adult men and women was drawn, and 40 names were randomly drawn, with an extra 10 as reserve. The selected people were contacted and invited to participate in the study. The study took place at the beginning of 2016 in a guest house in Touba, at the outskirts of the city, over 4 days, with one long morning session per day. The randomly selected participants were invited to come in the morning on a specific date, and were told they would receive a small allowance. The actual evaluation and experiment took place

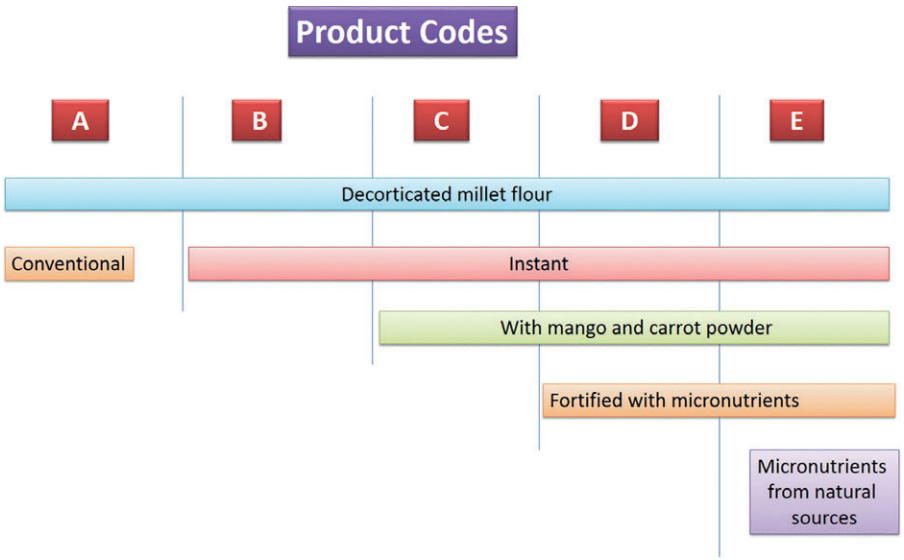

Figure 2. Product codes and the content of the different products.

Table 1. Composition of the products

Product code	Product description	Composition, in kg (% in brackets)					
		Pearl millet flour[a]	Sugar	Mango powder	Carrot powder	Hibiscus powder	Iron fortificant[b]
A	Traditional porridge	19 (90)	2.1 (10)	–	–	–	–
B	Instant porridge	22.5 (90)	2.5 (10)	–	–	–	–
C	Instant flavoured porridge	21.5 (86.2)	–	3.15 (12.5)	0.355 (1.4)	–	–
D	Instant flavoured porridge with micronutrients	20 (86.2)	–	2.88 (0.13)	0.33 (1.3)	–	0.005
E	Instant flavoured porridge with micronutrients from natural sources	20.25 (81)	–	3.15 (12.6)	0.355 (1.4)	1.25 (5)	–

[a] Raw for product A, instant for the other products.
[b] 5g is equivalent to 1/3 RDA.

in a large, central hall where five enumerators were seated at individual tables to conduct the affective test with one consumer at a time, while two enumerators were similarly set up to conduct the experiments. Food was prepared in a separate kitchen and, to accommodate the organisation of the enumerators, in small batches for about five consumers at a time. When food and enumerators were ready, participants were invited into the hall, individually or in small groups. They were registered, had the procedure briefly explained to them, then they were asked to give their informed consent and provided with their show-up fee. Participants who were invited but who did not show up were replaced by people from the reserve list in the order that they were drawn. On average, 50 consumers per day participated in the study.

Show-up fee, informed consent and socio-economic survey

Participants were individually welcomed and presented with a small show-up fee of 3000 FCFA (US$1 = 600 FCFA at the time of the study) to express our gratitude, help with transport fees, and to assure that they have the cash to participate in the experiment. The amount is set at roughly twice the estimated average WTP for the products, estimated at 1000 FCFA based on the prices of instant infant products in the local shops, plus a small transport allowance, giving a total of 3000 FCFA ($5).

One of six enumerators then explained the planned activities of the day to the participants, who were assured that they could stop and leave at any time, and were asked to give their informed consent. The enumerator signed the form as a witness. To assure double blinding, four enumerators conducted the affective tests and the experiment without information, while two other enumerators conducted the experiment with information.

Next, a set of demographic and socio-economic questions was asked to determine their age, education, wealth, income and so forth. The questionnaire was programmed with the software CSPro[26] onto electronic tablets (Kindle Fire, produced by Amazon, Seattle, WA, USA), which were subsequently used by the enumerators to enter each item of data immediately as it was collected.

Affective tests

Next, consumers were asked to evaluate the products with affective tests.

The conventional porridge was prepared by mixing ambient temperature water with normal flour to form a slurry. This was then poured into boiling water with stirring. The mixture was then brought to boil with vigorous stirring and then simmered by 30 min with occasional stirring. The instant porridge was prepared by stirring boiling water into the instantised flour.

Each participant was provided with about 50 g of each product, served at a temperature of about 50 °C. The five products were presented simultaneously on one tray, in systematic random order, and each participant was asked to evaluate each product in the established order.

Consumers were asked to taste and evaluate each product in a given order, which was randomised to avoid first sample and order bias. They were asked to provide a score on a five-point hedonic scale for different sensory attributes (dislike very much, dislike, neither like nor dislike, like, like very much). The five-point scale is much easier to use by enumerators interviewing consumers with limited or no education than the standard nine-point scale, which is typically used by consumers filling in the response sheets themselves, and has been used in several recent consumer studies in Africa.[13,25] The sensory traits used were appearance, aroma, texture in hand, flavour, texture in mouth, taste and overall appreciation (not an average, but a separate overall evaluation).The products were identified with a neutral symbol, randomly assigned (A, circle; B, square; C, triangle; D, diamond; E, rectangle) (Fig. 3, second column).The tests were conducted double blind; neither the enumerator nor the participants knew the content of the different products at this stage.

Economic experiments to determine WTP – information treatment

After the affective tests, the WTP of consumers was elicited with experimental auctions. For these auctions, participants were presented with the same five products, but now in dry flour format, packed in clear plastic bags with 250 g of flour each, with a plain white rectangular label inserted in the bag, labelled with symbols or symbols plus text printed in black ink, depending on the information treatment. It was explained that these were the same products they had just tasted, presented in the same order and with the same labels as during the affective tests.

The WTP for the products is based on their taste and sensory evaluation but also on other traits, in particular the ease of cooking (instant vs. traditional), the nutritional content (micronutrient), and the origin of the micronutrients (synthetic or natural). To distinguish the WTP for the sensory attributes from the WTP for the improved nutritional quality, the participants were randomly divided into two equal groups. Participants in Group 1 first conducted the experiment without any additional information on the content of the products, which were now presented with a label

Product	Labels with symbols only	Labels with symbols and information
A - traditional millet flour, decorticated		 **Farine de mi** 250 g **Produit au Sénégal**
Binstant decorticated millet flour		 **Farine de mil instantanée** 250 g **Produit au Sénégal**
C - instant decorticated millet flour, flavored with mango and carrot extract		 **Farine de mil instantanée avec extrait de mangue et carottes fortifiée avec des micro-nutriments** 250 g **Produit au Sénégal**
D - instant decorticated millet flour, flavored with mango and carrot extract, fortified with a synthetic premix of minerals and vitamins		 **Farine de mil instantanée avec extrait de mangue et carottes fortifiée avec des micro-nutriments** 250 g **Produit au Sénégal**
E - instant decorticated millet flour, flavored with mango and carrot extract, and fortified with natural products		 **Farine de mil instantanée Avec extrait de mangues et carottes Fortifiée avec des micro-nutriments extraits des produits naturels.** 250 g **Produit au Sénégal**

Figure 3. The different products, their codes, labels with symbols, and labels with both symbols and information.

with the same symbol used in the affective test. Therefore, their bids reflected the WTP for the sensory attributes. After the first round of experiments, the same participants (of Group 1) were given the information on the content of the products, and the experiment was repeated. Because doing the exercise twice might incur participant fatigue and bias the results, the other half of the participants, Group 2, went straight from the affective tests to the auctions with information. All information about the products was provided on the labels, together with the same symbols used during the affective test (Fig. 3).

The text on the labels contained a simple description of the product translated into French: (A) decorticated pearl millet flour; (B) instant decorticated pearl millet flour; (C) instant decorticated pearl millet flour - flavoured with mango and carrot extract; (D) instant decorticated pearl millet flour, flavoured with dried mango and carrot, fortified with micronutrients; and (E) instant decorticated pearl millet flour, flavoured with dried mango and carrot, fortified with micronutrients from natural sources. The labels were translated into the local language, Wolof, by the enumerators, and some time was provided for the participants to ask questions. The benefits of the instant pearl millet flours in terms of time and energy saved was explicitly explained, but not the benefits of the micronutrients. The natural source of the micronutrients, hibiscus, was also explained.

Experimental auction

During the experimental auction, participants' WTP for the different products was elicited using the BDM mechanism.[27] This procedure mimics an auction, but instead of bidding against other participants, the participant bids against a random price. This random price is drawn randomly from a particular distribution during the exercise. If the bid is higher than the random price, the participant buys the product at the random price; if the bid is lower, there is no transaction. This mechanism is incentive-compatible, meaning that the optimal bidding strategy of the participant is to bid its true WTP (unlike, for example, first-price sealed envelope auctions). Using a random price allows the exercise to be conducted individually, unlike real auctions.

The most convenient way is to use a random uniform distribution, around the mean expected value, from 0 to twice that value, with increments equal to the lowest currency value used in the local market, which in this case were coins of 50 FCFA. These numbers were printed on pieces of paper and put in an envelope.

To ensure participants understood the procedure, it was described and then it was emphasised that it was in the participant's best interest to reveal his or her true WTP, using a numerical example. Next, a test round was conducted, as this improves understanding and reduces bias.[28] For the test round, participants were asked to bid for two small packets of biscuits. One product was then selected randomly as binding, by letting the participant draw a random number from a set of prices (50, 100, 150) around the average value of the test-round product. The test-round experiment was conducted with real money, and if the participant won the auction, he or she purchased the test product at the random price.

The main round with the main product followed the test round. The participant was asked to make a bid for each of the five products. Then, one product was selected as binding, by asking the participants to draw a number from 1 to 5 from an envelope. Next, the participants drew the random price: a number from a uniform random distribution (from 50 FCFA to 600 FCFA, in increments of 50 FCFA, to approximately twice the value of the product, 300 FCFA), from another envelope. If the bid was higher than the random price, the participant purchased the product at the random price. The participants could pay with their show-up fee or (as change was often a problem), with money from their pocket. Although technically allowed, no participants offered zero bids. As the enumerators took care to explain clearly that the bids were binding, illustrated by the test round, and people were provided with sufficient money, people had no difficulties paying their bids when winning the auction. A few invitees did decline to participate after they were told the procedure.

Analysis

Affective tests used a five-point hedonic scale, so the resulting variables are ordinal in nature,[29] and an ordinal regression is the preferred method of analysis.[30,31] This model is also called the 'proportional odds' model by statisticians[30] and the 'ordered logit' model by economists.[32,33] In its basic form, respondents are asked to score two products, distinguished by a binary variable x, using a set of ordered categories. Let y be the score and $v_k = P(y \leq k)$, or the probability that a score y falls at or below a certain level k. The logarithm of the odds of v_k, also called the logit, is then modelled as a linear function of the independent variables, formally:

$$\text{Logit}\left(v_k\right) = \text{Ln}\frac{P\left(y \leq k\right)}{1 - P\left(y \leq k\right)} = \alpha_k + \beta' x \tag{1}$$

The coefficient β represents the change in the log odds (the logarithm of the odds) for a unit change in the explanatory variable x. If x is binary, β is the change in the log odds, and its exponent e^{β} represents the odds that one product is rated higher than the other, over the odds that the other product is rated higher, also called the odds ratio.[34]

The model can be expanded to analyse the scores for different products j, each with a vector of attribute vector x_j, by respondent i. The scores of different products by one respondent could be correlated, so an individual effect u_i needs to be added,[35] and the model becomes:

$$\text{Logit}\left(v_{ijk}\right) = \alpha_k + \beta' x_j + u_i \tag{2}$$

If the respondents are randomly selected, the standard procedure assumes that u_i is randomly distributed; it is also called the random effects model. Such models have been used to analyse farmer participatory evaluation of new technologies[35] and consumer evaluation of maize products.[7]

The effects of consumer characteristics z_i can also be included in the analysis using both direct effects (vector γ) and cross-effects (matrix A),[10] resulting in:

$$\text{Logit}\left(v_{ijk}\right) = \alpha_k + \beta' x_j + \gamma' z_i + \mathbf{x_j'} A \mathbf{z_i} + u_i \tag{3}$$

This model was estimated with the xtologit model with random effects with the software Stata, version 13.1 (College Station, TX, USA). Design factors include enumerator and order.

For the analysis of WTP, the dependent variable is WTP_{ij} or the willingness of consumer i to pay for product j, obtained through the economic experiment. It is a money metric in local currency, and therefore a quantitative variable on a ratio scale,[29] and can be analysed using a linear model. The WTP for the different attributes can be included as binary variables in a random effects model:

$$\text{WTP}_{ij} = \alpha + \beta' x_j + u_i + v_{ij} \tag{4}$$

Because the main interest here was the WTP for specific attributes, in this model x represents a vector of attributes, not products as in the ordinal regression. The attribute vector consisted of following binary variables: instant (vs. conventional), flavoured (yes/no), fortified (yes/no), and fortified with natural ingredients.

Finally, the effect of consumer characteristics was analysed by adding a vector z with age, gender and education level, to the model:

$$\text{WTP}_{ij} = \alpha + \beta' x_j + \gamma' z_i + \mathbf{x_j'} A \mathbf{z_i} + u_i + v_{ij} \tag{5}$$

The WTP models were estimated with the module xtreg in Stata version 13.1.

RESULTS

Consumer characteristics

Both women and men were well represented in the sample, but most participants had low incomes and wealth, and education levels were generally low (Table 2). More than half of the participants (54%) were women and the average age was 40.5 years, ranging from 17 to 88 years. Two thirds of participants had not received any formal education and average schooling was 2.5 years. The average family size of the participants was 10 people.

The participants were selected from peri-urban areas, and the socio-economic survey results indicated that most were urban. Only a quarter of participants owned farm land; for only 5% of them farming was the main occupation. Only 6% of participants owned cattle, but 35% owned poultry. Almost half (42%) of participants ran their own business. While many participants did not provide income details, most were able to report an annual income, with the average reaching almost 1 million FCFA ($1600) per year.

Affective tests

After the socio-economic questionnaire, consumers were asked to taste and evaluate the five products under study using affective tests. The products were presented in small cups (about 100 cL), freshly prepared, in random order and double-blinded. Participants were asked to score them, on a five-point scale, for five attributes and overall appreciation (Fig. 4). The results show that consumers generally appreciated the different products but made little, if any, distinction between them. Almost all evaluations were positive, and all products mostly received scores of 'good' (49%) or 'very good' (40%) for all criteria. Only product E received a few more negative scores, in particular for appearance and aroma. The natural source of micronutrients for this product was hibiscus, which added a distinct red colour and specific flavour.

Because the scores were ordered categorical data, they were analysed with ordinal regression [Eqn (2)]. However, no statistical differences were found between the scores for the different products, and for none of the different attributes (Table 3). As a result, the effect of demographic and socio-economic characteristics [Eqn (3)] was not further analysed.

Table 2. Descriptive statistics of the participants

Group	Variable	Mean	Std. dev.	*N*	None (%)[a]	Min.	Max.
Demographics	Female	0.54	0.5	201	–	0	1
	Age	40.5	14.3	201	–	17	88
	Education (years)	2.5	4.3	200	66.7	0	16
	Family size	9.9	6.0	195	–	1	40
Land (ha)	Owned	0.9	3.1	174	75.6	0	25
	Cultivated	0.5	2.1	180	81.1	0	20
	Uncultivated	0.2	0.9	180	81.1	0	8
	Other crops	0.4	1.9	175	–	0	20
Livestock	Cattle	0.3	1.7	200	93.5	0	14
	Sheep	1.1	3.3	200	78.6	0	30
	Goats	0.3	1.3	200	93.5	0	10
	Horses	0.1	0.6	201	–	0	5
	Donkeys	0.1	0.4	200	–	0	2
	Chicken	10.4	37.2	199	64.7	0	300
Income (FCFA/year)	Livestock sales	193 920	2 274 698	174	76.6	0	30 000 000
	Crop sales	13 795	69 236	173	79.6	0	500 000
	Salary	62 055	298 853	146	65.7	0	3 100 000
	Business	67 897	283 139	141	60.2	0	2 600 000
	Other sources	279 752	2 454 680	167	72.6	0	31 200 000
	Total	950 113	5 792 629	156	21.4	0	65 000 000

[a] Percentage of respondents whose level of education or ownership of assets was none.

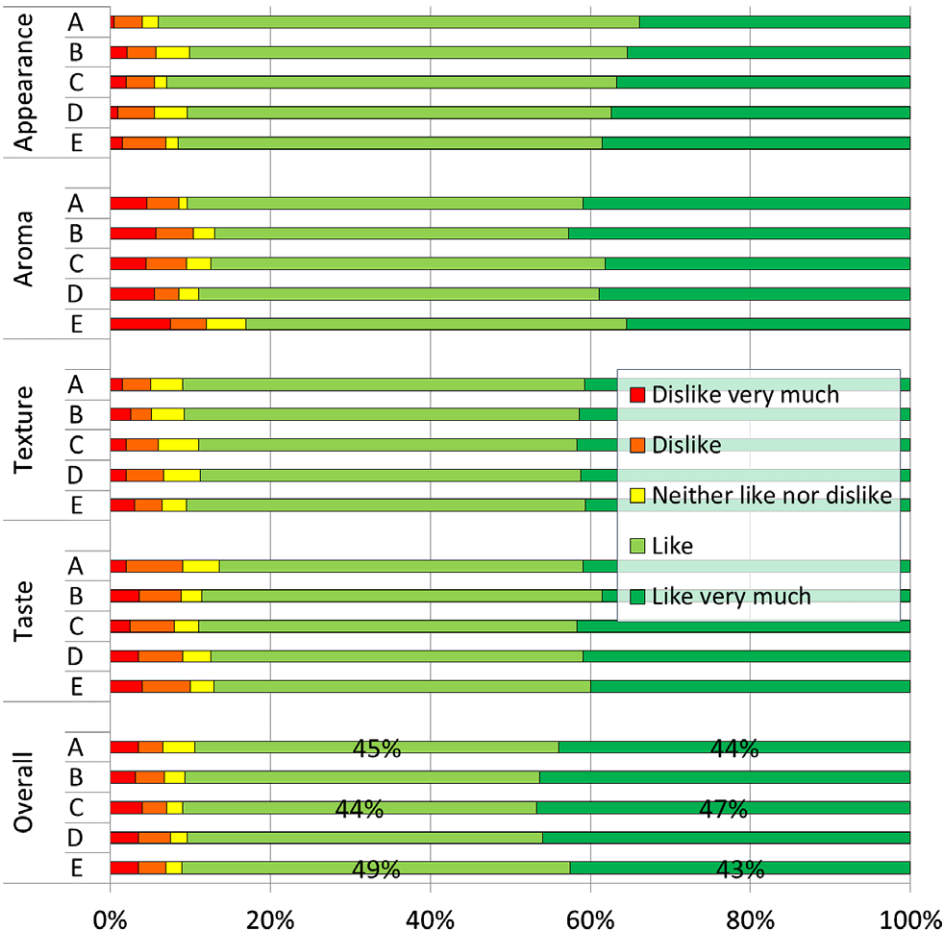

Figure 4. Results of the consumer affective tests, on a five-point hedonic scale, for attributes appearance, aroma, texture and taste, and overall appreciation (numbers are percentage of respondents who scored the specific product at that level for that attribute).

Table 3. Analysis of consumers' scores for different attributes and overall appreciation, using ordinal regression with random effects (base category is product A, traditional porridge)

		Appearance			Aroma			Texture			Taste			Overall appreciation		
Group	Variable	Coef.	SE	*P*	Coef.	SE	*P*	Coef.	SE	*P*	Coef.	SE	*P*	Coef.	SE	*P*
Products	Product B	−0.07	0.31	0.824	0.03	0.26	0.914	0.24	0.33	0.464	0.05	0.31	0.870	0.54	0.33	0.103
	Product C	0.38	0.31	0.225	−0.17	0.26	0.504	−0.03	0.32	0.920	0.38	0.31	0.223	0.59	0.33	0.075
	Product D	−0.30	0.31	0.330	−0.05	0.25	0.856	−0.21	0.32	0.514	−0.18	0.31	0.567	0.13	0.33	0.690
	Product E	0.20	0.31	0.521	−0.37	0.25	0.140	0.21	0.32	0.513	−0.11	0.31	0.721	0.15	0.33	0.647
Intercepts	/cut 1	−10.59	0.87	0.000	−6.01	0.42	0.000	−13.37	1.48	0.000	−10.55	0.89	0.000	−12.05	1.23	0.000
	/cut 2	−7.99	0.75	0.000	−4.92	0.39	0.000	−9.81	1.23	0.000	−7.83	0.79	0.000	−9.95	1.15	0.000
	/cut 3	−7.06	0.72	0.000	−4.36	0.37	0.000	−8.05	1.16	0.000	−6.86	0.77	0.000	−8.79	1.11	0.000
	/cut 4	1.52	0.46	0.001	0.65	0.31	0.039	0.59	0.79	0.458	0.84	0.58	0.145	0.18	0.71	0.801
Model	sigma2_u	24.589	4.93	–	11.6	1.87	–	40.756	11.6	–	32.2	6.42	–	40.11	9.27	–
	N observations	987	–	–	987	–	–	987	–	–	987	–	–	987	–	–
	N participants	201	–	–	201	–	–	201	–	–	201	–	–	201	–	–
	Wald chi^2 (4)	2.09	–	–	6.98	–	–	1.11	–	–	3.84	–	–	5.08	–	–
	Log likelihood	−618.6	–	–	−826	–	–	−595.4	–	–	−641	–	–	−574.5	–	–

Note: The coefficients are log-odds ratios, they represent a comparison of the four improved products with the base, product A, traditional porridge.

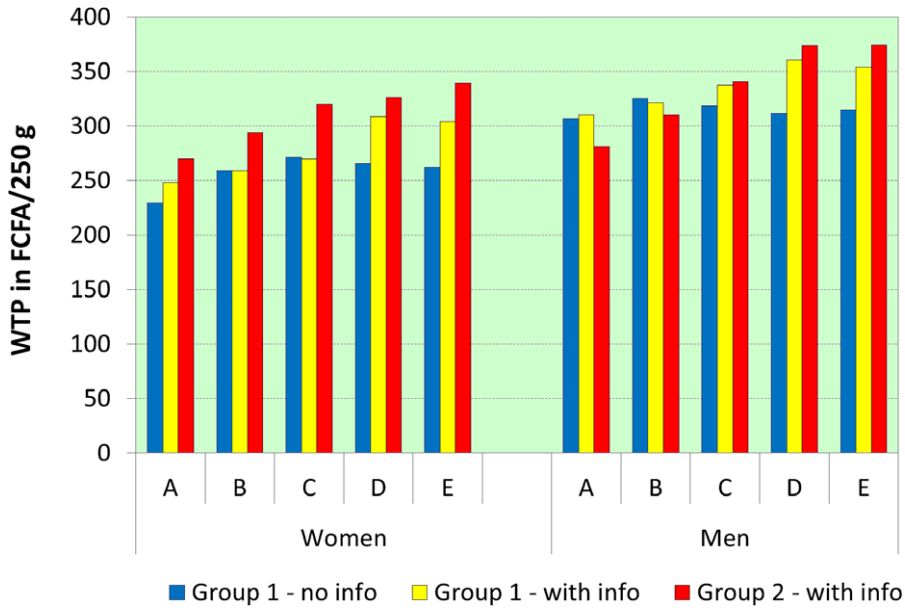

Figure 5. WTP for different pearl millet flour products (values in FCFA/250 g) (product codes as described in Fig. 2).

Willingness to pay – means, by gender

After the affective test, participants were asked to state their WTP for the five products, now packed in clear plastic bags of 250 g, using the incentive-compatible BDM mechanism to assure revealed preferences, either with or without additional information.

Participants of the first group, randomly assigned, were first asked to make their bids without receiving any additional information on the content of the products (Fig. 5). These bids showed no differences in WTP for the different products, except for a small difference between products A and C, and this for women only. However, there was a large difference between WTP from women (254 FCFA on average) and men (310 FCFA).

After this exercise, the participants of Group 1 were provided with the information on the content of the products, on labels containing both the symbol and the content information (Fig. 3). The results (Fig. 5), show only small changes in WTP for products A to C after the participants were given the information, but they do show a substantial premium for the products with added micronutrients (products D and E). There is, however, little or no difference between products D and E, indicating consumers do not express a willingness to pay a premium for micronutrients derived from natural sources. Further, men showed a small premium for product B (instant flour) while women did not.

The participants of Group 2 went straight from the affective tests to the WTP exercise with information. The WTP of this group was similar to those of Group 1 with information, except that there was now a clear premium for instant flour for both men and women (Fig. 5). So for both men and women, there is a clear increasing trend in WTP from A to D, but not between D and E, and the trend looks stronger among men.

Table 4. Mean willingness to pay (WTP) for improved pearl millet flours (250 g) and premiums as compared to WTP for traditional millet flour (results of pair-wise *t*-tests)

		WTP (FCFA/250 g)		Premium				
Group/information	Product	Mean	SD	FCFA	%	SD	*df*	*P*
Group 1, without information	A (traditional decorticated millet flour)	261	176	–	–	–	–	–
	B (instant decorticated millet flour)	270	167	9	3.4	61	76	0.213
	C (B + mango and carrot)	275	178	16	6.1	68	79	0.041
	D (C + micronutrients)	268	153	5	1.8	85	77	0.618
	E (C + micronutrients from natural sources)	267	204	4	1.6	87	76	0.673
Group 1, with information	A (traditional decorticated millet flour)	276	221	–	–	–	–	–
	B (instant decorticated millet flour)	302	191	11	4.3	84	96	0.188
	C (B + mango and carrot)	330	218	34	13.2	93	95	0.000
	D (C + micronutrients)	351	238	55	21.2	99	94	0.000
	E (C + micronutrients from natural sources)	357	223	49	18.7	115	95	0.000
Group 2, with information	A (traditional decorticated millet flour)	276	221	–	–	–	–	–
	B (instant decorticated millet flour)	302	191	27	10.2	116	97	0.025
	C (B + mango and carrot)	330	218	54	20.5	122	96	0.000
	D (C + micronutrients)	351	238	75	28.7	137	97	0.000
	E (C + micronutrients from natural sources)	357	223	68	25.9	140	70	0.000

Willingness to pay – statistical analysis with a pair-wise *t*-test

To check if consumers were willing to pay a premium for the traits of the new products, their mean WTP of the different products was calculated and compared to that of the control (Table 4), Participants of the group without information, for example, were willing to pay 261 FCFA for 250 g of product A, the base product (traditional, decorticated millet flour), 270 FCFA for product B (the instant version of that product), an increase of 9 FCFA or a premium of 9% for the trait 'instant'. Consumers in this group were willing to pay 275 FCFA for product C (the instant product with added mango and carrot powder), and so forth.

To test if the differences between products are significant, we do not compare the means directly, but use pair-wise *t*-tests. This test was used systematically to compare the improved products (from B to E) to the basic product (A), for the three sets of bids (Group 1 with and without information, and Group 2 with information) (Table 4). For ease of interpretation, the premiums were also calculated as a percentage over the WTP for product A.

Consumers in Group 1, before they were given information on the content of the products, did not express systematic increases in WTP for the improved products. This was to be expected, since their WTP was only based on the affective tests, in which no differences were observed. All premiums in this group were small and not significant, except for product C (instant MF with mango and carrot powder), for which consumers were willing to pay a small premium (6%). Upon further query, however, this premium was only observed for women (and amounted to 20% when calculated for them alone). This could therefore be a random effect, and would need to be confirmed by a repeat experiment.

The same participants from Group 1, after the first BDM exercise, were provided with the information on the products and offered a second chance to make bids. In this second round, they increased their bids for all products except for product B (plain but instant flour), with large and significant differences. These premiums amounted to 13% for the flavoured flour, and to 19–21% for those with micronutrients. There was no premium, however, if micronutrients came from natural sources.

The participants of Group 2 received the information on the products immediately after the affective tests, and were then asked to bid on the different products. In this group, the premiums for all the improved products were found to be large, positive and significant. The premium for instant flour was 27%, for flavouring with mango and carrots it was 54%, and for micronutrients it went up to 75%. The premium for micronutrients from natural ingredients, however, was slightly smaller (68%). However, the premiums for the last two products, D and E, were not statistically different from each other, indicating consumers are not willing to pay a premium for micronutrients from natural sources compared to micronutrients from other sources. There was no statistical difference between the average WTP for the different products between Group 1 after information and Group 2.

Willingness to pay – regression analysis

For a statistical analysis of the WTP for the different traits, a random effects model was estimated with the four different traits as binary variables (Eqn (4)): examined instant flour (products B to E), added flavour from mango and carrots (C to E), added micronutrients (D and E) and micronutrients from natural sources (E) (Fig. 2). The constant therefore represents the mean of the omitted category, product A (traditional millet porridge), and the coefficients represent the premium consumers are willing to pay to the different traits, compared to product A. They represent the monetary value the trait has to the consumers, in particular after they have received the information on those traits.

The results for the participants in Group 1 before they received information show they were not interested in paying a premium for the improved products: none of the coefficients in the regression are significant (Table 5, first block). This is expected, as participants did not score the improved products higher and did not have any information on their content. After they received the information, however, the bids of the participants in this group increased significantly for flavour (to 20 FCFA or 8% over the constant, the WTP for product A) and micronutrients added (25 FCFA or 9%). The coefficient for instant (11 FCFA or 4%) was positive but not significant in this group. Furthermore, the coefficient for natural sources was not significant.

The bids of Group 2, who went straight to the auction with information, were generally higher than those of the previous

Table 5. Analysis of consumers' willingness to pay (WTP) for improved pearl millet flours (in FCFA/250 g), using the short regression model [Eqn (4)]

		Group 1, without information			Group 1, with information			Group 2, with information		
Group	Variable	Coef.	Std. err.	$P>\|z\|$	Coef.	Std. err.	$P>\|z\|$	Coef.	Std. err.	$P>\|z\|$
Traits	Instant	11.8	9.5	0.216	11.3	9.3	0.222	26.5	11.9	0.026
	Flavour	4.4	8.8	0.619	20.5	9.2	0.026	27.7	11.9	0.020
	Micronutrient (MN)	−10.9	8.9	0.220	24.7	9.3	0.008	20.8	11.9	0.082
	MN from natural sources	0.5	8.9	0.956	−7.4	9.3	0.428	−4.0	13.2	0.760
	Constant	273.9	18.5	0.000	270.0	18.2	0.000	275.5	21.8	0.000
Model	σ_u	170.5	–	–	169.4	–	–	199	–	–
	σ_e	61.8	–	–	64.9	–	–	83.3	–	–
	ρ	0.9	–	–	0.9	–	–	0.85	–	–
	Number of observations	470	–	–	494	–	–	462	–	–
	Number of groups	100	–	–	101	–	–	98	–	–
	R^2: within	0.01	–	–	0.12	–	–	0.13	–	–
	R^2 between	0.01	–	–	0	–	–	0.01	–	–
	R^2 overall	0	–	–	0.01	–	–	0.02	–	–

group. In particular, the analysis showed a large and significant premium for instant flour (26 FCFA, or 10% over the constant compared to the non-significant coefficient of Group 1 without information). The premium for flavoured with mango and carrots was also high and significant (28 FCFA, compared to 20 FCFA for Group 1 with information). The premium for micronutrients was not as high (21 FCFA, and only marginally significant) but now lower than the premium in Group 1 with information (25 FCFA).

WTP – regression, long model

To analyse the effect of demographic and socio-economic characteristics of the participants on their WTP for the new products, these factors were included in the long model of Eqn (4) (Table 6). As in the previous model, there were no significant differences in WTP for the traits for the participants of Group 1 without information. After information, however, as in the previous model, the WTP analysis shows large and significant premiums for flavour and micronutrients, but not for natural sources of micronutrients. In the long model, however, the premium for instant flour was small, and now not significant, because of the cross-effect with education.

Few of the socio-economic variables were significant, however. In Group 1, without information, the effect of gender was large, but only marginally significant ($P=0.09$) (Table 6, first model). Otherwise, the effects of the consumers' socio-economic characteristics were only significant in Group 2 with information. In this group, of the direct effects, only income affected WTP, with a positive coefficient of 0.01, indicating WTP increases by 1% with income (Table 6, last model). In the cross-effects, the only significant cross-effect was that of education on WTP for instant flour. For every extra year of education, WTP for instant food increased by 6.5 FCFA. Including the cross-effect for education in the model, however, reduces the main effect for instant flour to the extent that it becomes insignificant. This might indicate that only people with education value instant flour.

DISCUSSION

The affective tests indicate that consumers did not differentiate between the different products in scoring for their sensory characteristics. As a result, participants who did not receive information on the products' content did not offer to pay premiums for quality traits. However, when participants were provided with that information, they showed an interest in paying a small premium (10%) for instant flour, and large premiums for added mangoes and carrots and for fortification with micronutrients. There was no added premium, however, if the micronutrients came from natural sources. Among participants, income had a positive effect on general WTP, but not for particular traits or quality. Education, on the other hand, increased WTP for instant flour.

Methodologically, several lessons were learned. First, the procedure of selecting the participants from the peri-urban areas of this particular city resulted in a large proportion of poor and uneducated participants. As the results indicated that WTP increases with income and WTP for instant flour increases with education, future studies concerning this type of cereal product in developing regions should focus on consumers with higher income and education levels, as these are more likely to be the final buyers of the improved products. In this respect, the goals of the project to develop sustainable businesses (based on customers who can afford the products) and improving the nutrition of low-income groups can be in conflict. Alternatively, future research could focus on informing consumers who are less likely to buy the new products about their nutritional benefits, making the production and processing of these products more efficient and cost-effective to make them more affordable for the poor.

Second, the results from the participants of Group 1 (who were asked to bid twice, the first time without information and the second time with information) after they were given information, were not as clear cut as those from Group 2, who went straight to the experiment after the affective test. Results from Group 2 showed more significant factors and with more precision in the estimates. Our experience indicates that participant fatigue could play a role: five products is already a substantial number, so to first evaluate them with affective tests, then do a WTP exercise without information, followed by another one with information, is probably demanding too much concentration and effort.

Third, another problem with the participants with little or no formal education was that many had difficulties reading or comprehending the information provided on the label. The information had to be translated and explained in the local language (Wolof). The enumerators were not initially prepared for this and some ad hoc training had to be organised. In the future, this information

Table 6. Analysis of consumers' willingness to pay (WTP) for improved pearl millet flours (in FCFA/250 g), using the long regression model [Eqn (5)]

	No information (first group)			With information (first group, after exercise without information)			With information (second group, immediately after affective test)		
WTP_noin	Coef.	Std. err.	$P>\|z\|$	Coef.	Std. err.	z	Coef.	Std. err.	z
Factors									
Instant	7.99	11.48	0.487	3.54	11.81	0.765	7.93	14.98	0.597
Flavoured	7.04	9.76	0.471	21.57	10.77	0.045	31.57	13.43	0.019
Micronutrients	−6.68	9.77	0.494	29.33	10.86	0.007	24.84	13.43	0.064
Micronutrients from natural sources	4.09	9.88	0.679	−3.86	10.82	0.721	−19.27	14.91	0.196
Male	82.70	48.31	0.087	58.46	45.45	0.198	42.76	52.30	0.414
Age	−1.37	1.57	0.382	−0.74	1.47	0.614	−1.31	1.76	0.458
Education (years)	−0.28	6.09	0.964	−1.04	5.71	0.855	−3.92	5.34	0.463
Income (1000 FCFA)	0.03	0.04	0.441	0.05	0.04	0.190	0.01	0.00	0.004
Education × instant	−2.55	2.08	0.221	1.27	2.07	0.540	6.53	2.11	0.002
Constant	304.21	69.50	0.000	272.32	65.40	0.000	310.77	72.87	0.000
Model									
Number of obs.	360	–	–	376	–	–	367	–	–
Number of groups	77	–	–	77	–	–	78	–	–
R^2 within	0.0087	–	–	1	–	–	0.171	–	–
R^2 between	0.0584	–	–	4.9	–	–	0.1341	–	–
R^2 overall	0.0618	–	–	5	–	–	0.1397	–	–
σ_u	181.83	–	–	169.88	–	–	204.00	–	–
σ_e	59.58	–	–	65.84	–	–	83.80	–	–
ρ	0.90	–	–	0.87	–	–	0.86	–	–
Wald χ^2 i (8)	7.01	–	–	52.16	–	–	70	–	–
Prob > χ^2	0.6361	–	–	0	–	–	0	–	–

needs to be unambiguously written, translated and practised, so all participants receive exactly the same information.

Fourth, comparing the experience of this study with previous studies indicates that the BDM mechanism, an individual procedure, is also convenient to estimate WTP in central location settings in urban areas. The five-point hedonic scale, in contrast to the nine-point scale, was easy to use with consumers with little or no education as its five classes are easily expressed in local languages.

Unlike previous studies, the WTP for the new products was decomposed into premiums for the different traits, such as instant and fortified with different ingredients. These premiums can now be compared to the cost of adding those traits to cereals in the production process to assess its economic efficiency. Since the results show that consumers in a low-income developing country are willing to pay a premium for better quality, in particular a small premium for instant flour and a large premium for added mangoes and carrot extract, and for micronutrients, the next step in the research is to estimate the cost of the added-quality traits and to compare them to premiums, and determine the products that are likely to find a market. Further, WTP for such products needs to be established among consumers, with higher income and education, either through a repetition of this experiment in more upscale markets, or a pilot marketing project.

Finally, this work highlights the difficulty inherent in many development-type projects trying to help create sustainable businesses while at the same time reaching the very poor with improved nutrition. As sustainability is essential, this goal needs to be pursued first, and profitable markets need to be identified, likely first among consumers with higher incomes and education levels. Once these markets have been explored and businesses are established, appropriate affordable products for the poor can be developed.

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REFERENCES

1 Taylor JRN, Barrion SC and Rooney LW, Pearl millet – new developments in ancient food grain. *Cereal Foods World* **55**:16–19 (2010).
2 Singh S, Gamlath S and Wakeling L, Nutritional aspects of food extrusion: a review. *Int J Food Sci Technol* **42**:916–929 (2007).
3 Yeu K, Lee Y and Lee SY, Consumer acceptance of an extruded soy-based high-protein breakfast cereal. *J Food Sci* **73**:S20–S25 (2008).
4 FAOSTAT, *FAOSTAT Production Data Base*. [Online]. FAO (2016). Available: http://faostat.fao.org/site/339/default.aspx [1 December 2016].
5 De Groote H and Kimenju SC, Consumer preferences for maize products in urban Kenya. *Food Nutr Bull* **33**:99–110 (2012).

6 Tomlins K, Ndunguru G, Stambul K, Joshua N, Ngendello T, Rwiza E *et al.*, Sensory evaluation and consumer acceptability of pale-fleshed and orange-fleshed sweetpotato by school children and mothers with preschool children. *J Sci Food Agric* **87**:2436–2446 (2007).
7 De Groote H, Gunaratna NS, Okuro JO, Wondimu A, Chege CK and Tomlins K, Consumer acceptance of quality protein maize (QPM) in East Africa. *J Sci Food Agric* **94**:3201–3212 (2014).
8 Meenakshi JV, Banerji A, Manyong V, Tomlins K, Mittal N and Hamukwala P, Using a discrete choice experiment to elicit the demand for a nutritious food: willingness-to-pay for orange maize in rural Zambia. *J Health Economics* **31**:62–71 (2012).
9 Chowdhury S, Meenakshi JV, Tomlins K and Owori C, Are consumers willing to pay more for biofortified foods? Evidence from a field experiment in Uganda. *Am J Agric Economics* **93**:83–97 (2011).
10 De Groote H, Kimenju SC and Morawetz UB, Estimating consumer willingness to pay for food quality with experimental auctions: the case of yellow versus fortified maize meal in Kenya. *Agric Economics* **42**:1–16 (2011).
11 De Groote H, Tomlins K, Haleegoah J, Awool M and Frimpong BN, Assessing rural consumers' WTP for orange, biofortified maize in Ghana with experimental auctions and a simulated radio message, in *Conference of the African Agricultural Economics Association, Cape Town, 19–23 September* (2010). [Online]. Available: https://www.researchgate.net/profile/Keith_Tomlins/publication/254384017_Assessing_Rural_Consumers'_WTP_for_Orange_Biofortified_Maize_in_Ghana_with_Experimental_Auctions_and_a_Simulated_Radio_Message/links/0deec534ba1f24532c000000.pdf
12 Banerji A, Chowdhury S, De Groote H, Meenakshi JV, Haleegoah J and Ewool M, Using elicitation mechanisms to estimate the demand for nutritious maize: evidence from experiments in rural Ghana. *Can J Agric Economics* (2013). [Online]. Available: http://cdm15738.contentdm.oclc.org/utils/getfile/collection/p15738coll2/id/127754/filename/127965.pdf.
13 Gunaratna NS, Bosha T, Belayneh D, Fekadu T and De Groote H, Women's and children's acceptance of biofortified quality protein maize for complementary feeding in rural Ethiopia. *J Sci Food Agric* **96**:3439–3445 (2016).
14 Meilgaard M, Civile GV and Carr BT, *Sensory Evaluation Techniques,* 4th edition. CRC Press, Boca Raton, FL (2007).
15 Costanigro M, Kroll S, Thilmany D and Bunning M, Is it love for local/organic or hate for conventional? Asymmetric effects of information and taste on label preferences in an experimental auction. *Food Qual Pref* **31**:94–105 (2014).
16 Sitz BM, Calkins CR, Feuz DM, Umberger WJ and Eskridge KM, Consumer sensory acceptance and value of domestic, Canadian, and Australian grass-fed beef steaks1. *J Anim Sci* **83**:2863–2868 (2005).
17 Umberger WJ, Feuz DM, Calkins CR and Killinger-Mann K, U.S. consumer preference and willingness-to-pay for domestic corn-fed beef versus international grass-fed beef measured through an experimental auction. *Agribusiness* **18**:491–504 (2002).
18 Stefani G, Romano D and Cavicchi A, Consumer expectations, liking and willingness to pay for specialty foods: Do sensory characteristics tell the whole story? *Food Qual Pref* **17**:53–62 (2006).
19 Jones LV, Peryam DR and Thurstone LL, Development of a scale for measuring soldiers' food preferences. *J Food Sci* **20**:512–520 (1955).
20 Vickrey W, Counterspeculation, auctions, and competitive sealed tenders. *J Finance* **16**:8–37 (1961).
21 Wayua FO, Shibia MG, Mamo MS, Bailey D and Coppock DL, Willingness to pay for improved milk sensory characteristics and assurances in northern Kenya using experimental auctions. *Int Food Agribusiness Manag Rev* **12**:69–88 (2009).
22 Bekele AD, Beuving J and Ruben R, How do health information and sensory attributes influence consumer choice for dairy products? Evidence from a field experiment in Ethiopia. *Int J Qual Reliability Manag* **34**:667–683 (2017).
23 Demont M, Zossou Er, Rutsaert P, Ndour M, Van Mele P and Verbeke W, Consumer valuation of improved rice parboiling technologies in Benin. *Food Qual Pref* **23**:63–70 (2012).
24 Demont M, Rutsaert P, Ndour M, Verbeke W, Seck PA and Tollens E, Experimental auctions, collective induction and choice shift: willingness-to-pay for rice quality in Senegal. *Eur Rev Agric Economics* **40**:261–286 (2013).
25 De Groote H, Chege CK, Tomlins K and Gunaratna NS, Combining experimental auctions with a modified home-use test to assess rural consumers' acceptance of quality protein maize, a biofortified crop. *Food Qual Pref* **38**:1–13 (2014).
26 United States Census Bureau, *Census and Survey Processing System (CSPro)*. United States Census Bureau, Washington (2016).
27 Becker GM, DeGroot MH and Marschak J, Measuring utility by a single-response sequential method. *Behav Sci* **9**:207–299 (1964).
28 Morawetz UB, De Groote H and Kimenju SC, Improving the use of experimental auctions in Africa: theory and evidence. *J Agric Resource Economics* **36**:263–279 (2011).
29 Stevens SS, On the theory of scales of measurement. *Science* **103**:677–680 (1946).
30 McCullagh P, Regression models for ordinal data. *J Royal Stat Soc Series B (Methodological)* **42**:109–142 (1980).
31 Coe R, Analyzing ranking and rating data from participatory on-farm trials, in *Quantitative Analysis of Data from Participatory Methods in Plant Breeding*, ed. by Bellon MR and Reeves J. CIMMYT, Mexico, DF, pp. 6–65 (2002).
32 Train KE, *Discrete Choice Methods with Simulation*. Cambridge University Press, Cambridge, UK (2003).
33 Greene WH, *Econometric Analysis*. McMillan Publishing Company, New York (1991).
34 Bellon MR, Adato M, Becerril J and Mindek D, Poor farmers' perceived benefits from different types of maize germplasm: The case of creolization in lowland tropical Mexico. *World Develop* **34**:113–129 (2006).
35 De Groote H, Rutto E, Odhiambo G, Kanampiu F, Khan Z, Coe R *et al.*, Participatory evaluation of integrated pest and soil fertility management options using ordered categorical data analysis. *Agric Syst* **103**:233–244 (2010).

