Research Article

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Consumer acceptance of quality protein maize (QPM) in East Africa

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Abstract

BACKGROUND: Undernutrition in sub-Saharan Africa remains problematic, and quality protein maize (QPM) can benefit populations whose diets are heavily based on maize and who are consequently at risk for inadequate intakes of quality protein. However, changes in the chemical composition of QPM may affect its sensory characteristics and, hence, acceptance. Acceptance tests were therefore conducted to evaluate QPM varieties in three East African countries using central location tests with one or two varieties in each country, using the most popular preparations: *ugali* (Tanzania), *githeri* (Kenya) and *injera* (Ethiopia). In total, 281 urban and rural consumers of both sexes and varying levels of education evaluated the products on standard sensory criteria: appearance, aroma, texture, taste and overall, using a Likert scale.

RESULTS: The results show that African consumers can differentiate QPM products from their conventional counterparts, indicating that the QPM trait results in distinguishable sensory changes. Analysis by ordinal mixed regression models showed that consumers found QPM acceptable and even preferable to conventional maize.

CONCLUSION: The sensory characteristics of QPM are therefore no impediment to its adoption; on the contrary, when coupled with good agronomic performance, they may help its utilization, leading to a positive impact in nutritionally vulnerable populations.

Supporting information may be found in the online version of this article.

Keywords: quality protein maize; East Africa; consumer acceptance; affective test; ordinal regression; mixed models

INTRODUCTION

Despite global efforts towards the first Millennium Development Goal to eradicate extreme poverty and hunger, large disparities in progress exist regionally.[1] Progress has slowed towards nutritional goals, in large part due to poor prospects in all regions of sub-Saharan Africa.[2] Moreover, food production can barely keep up with the still rapidly increasing population, especially in Africa, where per capita food production in the last decennium was lower than in the 1960s.[3]

To improve this situation, plant breeders are developing new crop varieties with increased nutritional value, such as quality protein maize (QPM; biofortified with essential amino acids) or orange-fleshed sweet potato, yellow cassava and orange maize (biofortified with provitamin A carotenoids).[4] Biofortification of staple crops is a cost-effective way to improve the diets of rural populations, which are often of the poorest quality, and to improve their nutritional status.[5,6]

For biofortified crops to be adopted and hence improve the nutritional status and health of target populations, they must be appreciated in their common food preparations. Biofortification can alter the organoleptic qualities of crops, however, so their consumer acceptability needs to be tested. Because sensory evaluation techniques have largely been developed for urban consumers in developed countries, special care is needed to ensure that methods are appropriate and, where necessary, adapted to the special needs and characteristics of the poor consumer, who may be illiterate and have limited experience in this type of exercise. The main target of biofortified crops is rural households that mostly consume their own production, and their common food preparations using these staples should receive particular attention.

In East and Southern Africa, the major staple food is maize, which has a poor balance of essential amino acids.[7] People whose diets

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are based on maize and who have limited access to legumes and animal food sources are therefore at risk of inadequate intakes of quality protein and, in particular, lysine.[8] To counter maize's poor amino acid balance, QPM was developed with higher levels of lysine and tryptophan than conventional maize.[9] QPM is based on the discovery in the 1960s of a specific gene, *opaque-2* (*o2*), that almost doubles the lysine and tryptophan content of the maize endosperm, dramatically improving its protein quality.[10] Unfortunately, the *o2* gene was also associated with soft opaque kernels and poor agronomic performance. Over a period of almost 30 years of targeted conventional plant breeding, these problems were overcome using natural genetic modifiers. A group of new maize varieties, collectively called QPM, was developed with improved protein quality as well as agronomic and storage qualities similar to conventional maize.[9,11]

Randomized controlled trials in several developing countries have demonstrated the positive effect of QPM consumption on the nutritional status of children, in particular in Ethiopia,[12] India[13] and Nicaragua.[14] A meta-analysis of nine of these trials in five countries showed that consumption of QPM instead of conventional maize leads to a 12% increase in the rate of growth in weight and a 9% increase in the rate of growth in height in infants and young children with mild to moderate under-nutrition from populations in which maize is the major staple food.[15]

However, to have nutritional impact, consumers must accept QPM varieties in the preparation of common foods in local diets. The *o2* gene changes the protein composition and stacking of starch in the endosperm.[11,16] The appearance of the kernel is also altered to a soft, chalky phenotype that is unattractive to maize growers in developing countries.[9] In Colombia, however, *o2* maize showed good acceptability in most preparations tested,[17] although, with a three-point Likert scale and only 20 participants, differences were hard to distinguish.

In developing QPM, plant breeders specifically selected for conventional kernel characteristics along with improved protein quality. Therefore, these conventional kernel characteristics, which are expected by farmers, are a required feature of modern QPM varieties. However, having conventional kernel characteristics does not ensure that a variety will have similar or equally acceptable sensory characteristics as conventional maize, necessitating consumer acceptance testing. In Ghana, QPM varieties were preferred to the local conventional maize in some preparations and were equally accepted in others.[18] In Nigeria, finally, sensory evaluation of stiff porridge prepared from QPM and conventional maize varieties showed no significant difference in flavor, taste, color or overall acceptability.[19]

Currently, QPM varieties are being disseminated and promoted in East Africa,[20] but their acceptance among consumers has not yet been studied. The limited number of past consumer acceptance studies on QPM had methodological issues in both their design and analysis. In particular, researchers as well as participants were often aware of the identity of varieties being evaluated, allowing personal biases to play a role in evaluation. Studies using a single QPM variety or a single conventional maize variety were not able to attribute differences in consumer acceptance specifically to the quality protein trait, as those differences could be due to other characteristics specific to the variety being tested. Other factors that affect participants' responses, such as participant demographics, the order in which food samples were presented, and other characteristics of the evaluation, were not considered or controlled. Finally, evaluations were typically done using ordinal scales with multiple evaluations by each participant, but analyses did not account for the nature and correlated structure of these data. In this study, therefore, we assessed consumer acceptance with affective tests using locally available QPM varieties in three common food preparations in the three major East African maize-producing countries, while making several methodological improvements.

METHODOLOGY

Concepts and overview

Consumers derive satisfaction, not from the goods themselves, but from the attributes these provide.[21] Therefore, sensory properties are an important part of the study of consumer acceptance of new food products, and typically involve several criteria, such as smell or taste, which emanate from a combination of attributes. The importance of the attributes or criteria not only depends on the specific product, but also on its preparation, the cultural environment and consumers' socioeconomic characteristics. To evaluate a product, consumers are asked to use a particular metric or scale, [22] often a Likert scale.[23] In sensory evaluation, a trained panel tries to objectively judge the new products on the different criteria, while in affective tests regular consumers are asked how much they like the products, based on a limited range of criteria. Affective tests are preferably conducted with randomly selected participants, while the evaluation should be double-blind and the order of presentation random.

Because this was the first time that QPM was evaluated in East Africa, and the budget was limited, the central location method[22] was preferred. This method allows for many people to participate in a relatively short time in a well-controlled environment. The three countries with the highest levels of maize production and consumption in the region were selected: Kenya, Ethiopia and Tanzania. Within each country, the place or region was chosen based on the availability of grain and the dissemination activities of the Quality Protein Maize Development (QPMD) project. In each country, QPM and conventional maize were evaluated with the most important maize preparation in the country or region, on the standard sensory criteria, organized by teams from the respective collaborating organizations of the QPMD project.

Study design

In all countries, the study took place in a central, urban location, complemented with two central rural locations in Kenya. All participants were adults, both men and women, with varying degrees of education. Before consumer acceptance, information was collected on individual characteristics such as gender, age and education. The methods were first developed and tested with urban consumers in a small urban center in Kenya (Embu), for convenience and cost reasons, and subsequently adapted and used with nearby rural consumers. In the next country, Ethiopia, the study only took place in the capital because of budgetary reasons, but care was taken to include consumers from a wide range of backgrounds, including scientists, students and illiterate workers. In Tanzania, finally, the research station where the study took place is situated on the outskirts of the provincial capital, Arusha, and the food consumption habits of its staff were likely similar to the rural households around them. These studies were the start of a wider range of studies to develop the methods for the ultimate target audience: rural consumers.

The first evaluations were conducted in Kenya, in November and December 2007, by the Kenya Agricultural Research Institute (KARI) at one urban center and two rural communities in Embu District. The urban evaluation took place at the Agricultural Training Centre (ATC) in Embu. Notices were posted at KARI

Table 1. Study design with number of sites and participants, products and varieties, and evaluation criteria, by country

Factor	Category	Tanzania	Kenya	Ethiopia
Site	Urban	Arusha (SARI)	Embu (ATC)	Addis Ababa (EPHI)
	Rural		Mukuria and Itabua	
Number of participants		30	131	120
Maize preparation tested		*Ugali*	*Githeri*	*Injera*
Ingredients	Product 1	Maize	Maize and beans	Maize and *teff* (50%-50%)
	Product 2			Maize and *teff* (80–20%)
	Product 3			*Teff*
Varieties	QPM Variety 1	Lishe K1	KH631Q	BHQP542
	QPM Variety 2		WSQ104	Melkassa 6Q
	CM Variety 1	Local grain	EMCO	BH540
	CM Variety 2		H513	Melkassa 2
Criteria included in evaluation	Appearance	√	√	√
	Aroma	√		√
	Pliability			√
	Texture		√	
	Texture in hand	√		√
	Texture in mouth	√		√
	Taste	√	√	√
	Overall acceptance	√	√	√

and ATC to invite volunteers, and 25 men and 25 women participated. The rural evaluations were conducted with two farmer groups: in Mukuria sub-location (Kyeni Division), with a group of single HIV-positive mothers of which 57 participated, and in Itabua sub-location (Central Division), with a mixed group of which 14 men and 10 women participated.

In Ethiopia, the sensory evaluation was conducted in December 2009 by the Ethiopian Public Health Institute (EPHI), previously the Ethiopian Health and Nutrition Research Institute (EHNRI), in their food science laboratory in Addis Ababa. Volunteers were recruited from among educated staff members, of which 60 participated (34 women), students affiliated with the institute (with 30 participants, of which 15 were female) and staff with limited or no schooling (30 participants, of which 19 were women). Because of the complex design and large number of products (nine), each volunteer participated in two sessions on separate days, with five products evaluated per session.

The last country was Tanzania, where the evaluations were organized in January 2010, by the Selian Agricultural Research Institute (SARI), at their station in Arusha, the regional capital. Volunteers from the SARI staff were invited and 30 participated, of which 12 were women.

To facilitate the presentation and the understanding, however, from here on we will present the methods and the results from the simpler to the more complex design, starting with Tanzania, followed by Kenya and ending with Ethiopia.

The products

The products evaluated were different preparations, made from QPM or conventional maize varieties, or mixed with *teff* in Ethiopia. While, ideally, QPM varieties converted from conventional varieties should be paired with their conventional counterpart to isolate the QPM trait in the evaluation, no such near-isogenic pairs were available. In Tanzania, only one QPM variety – Lisle K1 – was available, and it was compared to conventional maize purchased as grain from the market, but the variety could not be identified. In Kenya, two QPM varieties were available – KH631Q and WSQ104 – and they were evaluated along with two popular conventional maize varieties: Embu Composite (EMCO) and KH513. In Ethiopia, four varieties were evaluated, paired by their targeted agro-ecological zone: the medium maturing BH540 and its QPM counterpart BHQP542; and the dryland variety Melkassa 2 and its QPM counterpart Melkassa 6Q.

In each country, participants compared the QPM and conventional maize (CM) varieties using the most commonly consumed preparation for the region (Table 1). In Tanzania, this preparation was *ugali*, *a* stiff, unfermented porridge, prepared by gradually adding maize flour to boiling water and stirring continuously until cooked. *Ugali* is the most common staple food in Tanzania[24] and is also popular in Kenya.[25] The product was prepared in the kitchen of the institute by one single cook. Both varieties were purchased from the local market, milled locally, packed and labeled with a triangle for QPM and a circle for conventional maize, so neither the cook, the enumerators nor the participants knew which one was QPM.

In Kenya, the major maize preparation of the region was identified by farmers during participatory rural appraisals[26] as *githeri*, a mixture of boiled maize kernels and beans in a ratio of 2:1. *Githeri* is popular in other parts of the country, including the capital, where it ranks second after *ugali*.[25] The four varieties were identified by randomly generated three-digit codes, only known to the lead researcher.

In Ethiopia, the most common staple food is *injera*, a leavened bread made from fermented dough.[27] Traditionally, it is made from *teff*, an indigenous cereal, but it is often mixed with other cereals, especially with the much cheaper maize. A study conducted at the Awassa College of Agriculture found that injera made from a mix of teff, wheat, sorghum and maize flour, each at 25%, was acceptable in sensory evaluation. The mixture was 36.6% cheaper than pure teff, and the nutritional value was slightly better.[28] For this study, nine *injera* products were evaluated: one from pure *teff* and eight from maize/*teff* mixtures, with either 50% or 80% maize from one of the four maize varieties. Each variety was coded with a randomly generated three-digit code.

Scoring for different criteria

All products were evaluated on the basic sensory criteria using a standard Likert scale.[23] In Tanzania, participants were staff members of SARI, all with secondary education or more, so the more precise nine-point scale was used. The scale was centered on a value of 5 (average), with the lowest value 1 (=extremely bad), the highest 9 (=extremely good), and other qualifications were 'moderately' and 'very'. Elsewhere, farmers and illiterate workers participated, so the simpler five-point scale was used ('very bad', 'bad', 'fair', 'good' and 'very good'). This basic scale can be used in most languages and on most relevant criteria, even orally, but is less precise and clearly an ordinal variable, requiring specific statistical methods.[29] The terms 'good' and 'bad' are common verbal qualifiers for rating scores and a comparative study found them appropriate to evaluate quality levels.[30] We found them the easiest to translate accurately in the languages used during evaluations and discussions (English and Kiswahili in Tanzania, Kiembu in Kenya and Amharic in Ethiopia). They allow the scale to remain balanced and hence suitable for statistical analysis, and can be interpreted within the context of the experiment.

The four general criteria in sensory evaluation are appearance, aroma, texture and taste. Because many African dishes are consumed using the hands, the texture in the hand was evaluated separately from the texture in the mouth in Tanzania and Ethiopia. In Tanzania, discussions with focus groups and key informants informed the choice of the criteria. In Kenya, the evaluation criteria for *githeri* were elicited during group discussions in Kiembu, the local language of the district, resulting in taste, texture and appearance. In Ethiopia, sensory evaluation of *injera* is frequently done at EPHI, and involves the standard criteria as in Tanzania. But because *injera* is also used to pick up sauces and other food items, its pliability is also considered important. For cross-country comparison, an overall evaluation was added to all products.

The participants evaluated each food preparation in randomly assigned orders and did not return to re-evaluate an earlier preparation. Drinking water was provided between evaluations of each preparation to minimize the effect of previous scores on subsequent scores, but no sauce or side dishes were provided. In Tanzania and Kenya, the products were offered in randomized order. In Ethiopia, the nine products were split into two rounds: one round contained the control *injera* from pure *teff* and *injera* from 50% maize mixtures using each of the four varieties, while the other round contained the control *injera* from pure *teff* and *injera* from 80% maize mixtures using the four varieties. The rounds were randomly assigned, and within each round the five treatments were presented in a randomized order. All studies were double-blind, i.e. neither the researchers nor the participants knew which maize variety was used to make any of the food preparations. The data collection sheets and the questionnaires for the three countries can be found in the supplementary materials.

Sample size

The number of participants in Ethiopia and Kenya was determined using the sample size formula for paired data derived by Connett *et al.*,[31] which provides an upper bound on the required number of discordant responses.[32,33] Assuming 80% power, a 0.05 significance level, pairs of responses distributed uniformly over a five-point scale (i.e. a proportion of discordant pairs of 0.8) and an odds ratio for discordant pairs of 1.8, then at least 118 participants were required in each country. The sample size in Tanzania was limited by available resources and was sufficient to detect an odds ratio of 3.2 using a nine-point scale.

Analysis

The nine-point scale used in Tanzania can be argued to approximate an interval variable, so means were first compared with a paired *t*-test to analyze whether the difference was significantly different from zero. In Kenya and Ethiopia, the five-point scale was used, which is clearly ordinal[29] and for which the preferred analysis is ordinal regression.[34,35] Because each respondent was asked to evaluate several products, an individual random effect was added to account for differences in scoring among respondents and correlation of scores from the same respondent.[36]

Ordered-response models typically assume that the scores represent ordered segments of a utility distribution.[37] The values of the latent variable U represent quantities and can be analyzed using standard quantitative methods such as the linear model:[38]

$$U_i = \boldsymbol{\beta}'\mathbf{x}_i + \epsilon_i \tag{1}$$

where U_i represents the utility of individual i, $\mathbf{x}_i$ is a vector of variables influencing the ith individual's utility and choice, $\boldsymbol{\beta}$ is a vector of parameters to be estimated and ϵ_i is the error term. The probability of the scores y can now be derived from this model by assuming the error term ϵ has a logistic distribution,[39] and the log-likelihood function can be constructed and maximized to estimate the parameters. Let $\nu_k = P(y \leq k)$, or the probability that a score y falls at or below a certain level k, and the logit, or the logarithm of the odds of ν_k, can then be modeled as a linear function of the independent variables, formally:

$$logit\left(\nu_k\right) = \ln \frac{P\left(y \leq k\right)}{1 - P\left(y \leq k\right)} = \alpha_k + \boldsymbol{\beta}'\mathbf{x} \tag{2}$$

It follows that the ratio of the odds of the event $y \leq k$ at $\mathbf{x} = x_1$ and $x = x_2$ is independent of the level k, and that the log of the cumulative odds for all the categories k are linear (or proportional) to the independent variables, regardless of k, hence the name 'proportional odds' model,[34] also called the ordered logit model.[38,39] The coefficient $\boldsymbol{\beta}$ represents a change in the log odds (the logarithm of the odds) for a unit change in the explanatory variable x. Hence, if x is binary, as when comparing a new product to an old one, the coefficient $\boldsymbol{\beta}$ represents the change in the log odds due to the new product. Its exponent, e^{β}, represents the odds that the new product is rated higher over the odds for the old product, also called the odds ratio.[40] The proportional odds assumption can be evaluated using a score test (Peterson and Harrell, 1990).

To analyze the effect of the products on the scores from the sensory evaluation, let $\mathbf{x}_j$ be a vector of attributes for product j, and $\boldsymbol{\beta}$ a vector of parameters. Adding a random individual effect u_i, the model becomes

$$\text{logit}\ \left(\nu_{ijk}\right) = \alpha_k + \boldsymbol{\beta}'\mathbf{x}_j + u_i \tag{3}$$

The order of presentation and other aspects of the study design can be included in the set of attributes, $\mathbf{x}_j$, and consumer acceptance can now conveniently be analyzed by the coefficients of this short model.

Evaluation of new products can also differ by the characteristics of the consumers, in particular gender, education and age. To analyze the combined effects of the product attributes j and consumer characteristics i on the cumulative odds of score y_{ij}, a mixed-effects model was used with a product attributes vector $\mathbf{x}_j$,

Table 2. Characteristics of the participants[a]

Characteristics	Tanzania All ($n = 30$)	Kenya Embu ($n = 50$)	Kenya Mukuria ($n = 57$)	Kenya Itabua ($n = 24$)	Kenya All ($n = 131$)	Ethiopia Staff with education ($n = 60$)	Ethiopia Students ($n = 30$)	Ethiopia Staff without education ($n = 30$)	Ethiopia All ($n = 120$)
Female (%)	40	50	100	42	70	56	50	63	58
Age (years)	42.3	33.1	43.2	54.0	41.4	30.3	20.0	44.0	33.7
(SD)	(10.4)	(10.1)	(16.2)	(14.1)	(15.6)	(10.0)	(1.9)	(8.8)	(11.4)
Education (years)	15.1	11.8	7.9	8.4	9.5	14.5	14.2	0.0	10.9
(SD)	(4.9)	(3.4)	(7.3)	(3.7)	(5.7)	(2.0)	(1.3)	(0.0)	(6.5)
Farming experience (years)	–		21.6	22.6	21.9	–		–	–
(SD)	–	–	(17.0)	(12.3)	(15.6)	–		–	–
Farm size (acres)		–	2.9	2.7	2.8	–		–	–
(SD)		–	(3.2)	(2.2)	(3.0)	–		–	–

[a] Values are means (with standard deviations in parentheses) or percentages as indicated.

a consumer characteristics vector $\mathbf{z}_i$, a cross-effects matrix $\mathbf{A}$, and an individual disturbance u_i:[41]

$$\text{logit}\left(v_{ijk}\right) = \alpha_k + \beta'\mathbf{x}_j + \gamma'\mathbf{z}_i + \mathbf{x}_j'\mathbf{A}\mathbf{z}_i + u_i \qquad (4)$$

This long model allows analysis of the effects of both product and consumer characteristics, as well as their cross-effects, while taking into account the possible correlation between scores for different products by the same consumer.

RESULTS

Characteristics of participants

About two-thirds of all participants were female, but it was slightly more in Kenya, where one of the participating groups was a women-only group (Table 2). All respondents were adults, with an average age of 39 years. The respondents in urban Kenya were relatively younger (33), as were the students in Ethiopia (20), while the rural respondents in Kenya were older (43 among the women's group; 54 among the mixed group).

Most respondents were educated, with an average level of 10 years. Education was highest in Tanzania (15 years), where all respondents came from the staff of the research institute. Education of respondents was high in urban Kenya (12 years), and in Ethiopia among the educated staff (15) and the students (14). Education was lowest in rural Kenya (but still 8 years on average) and among the uneducated staff in Ethiopia. The respondents in rural Kenya were all farmers, with an average farm size of 2.8 acres and an average farming experience of 22 years.

Consumer acceptance of *ugali* in Tanzania

In Tanzania, 30 staff members of the collaborating research institute, SARI, evaluated the acceptance of *ugali*, a stiff maize porridge, made from either QPM or conventional maize. Participants were asked to evaluate samples made from both maize types, on five different criteria and overall, on a nine-point Likert scale (1 = extremely bad, 2 = very bad, 3 = bad, 4 = moderately bad, 5 = fair, 6 = moderately good, 7 = good, 8 = very good, and 9 = extremely good). From the nine options, however, very few participants used the four lowest ratings, and 99% of the responses were in the categories 'fair' or better.

In a first analysis, assuming the scores approximate interval variables, the mean scores were compared (Table 3). The results show that QPM *ugali* is generally preferred over its CM counterpart: in the overall evaluation it received an average score of 1.1 units higher, and it also scored better for all criteria except appearance. The scores for QPM were significantly larger for texture in mouth (1.3), for taste (1.4), and, to a lesser extent, for the related aroma (0.9).

Because the scores are ordinal variables, ordinal regression is indicated as it does not assume that the data follow a continuous interval scale. Estimation of the short model (Eqn (3)) indicates that consumers did not distinguish between the appearance of QPM and CM *ugali* and found them similarly acceptable (Table 3). For all other criteria, however, QPM scored better, as indicated by the sign and the significance of the coefficients. The coefficients for QPM in the ordinal regression are log-odds ratios. For better interpretation, they can be transformed into odds ratios by taking the exponent. The odds ratio for the evaluation of QPM *versus* conventional maize for aroma, for example, equals exp(1.9) = 6.9, indicating that the odds of QPM having a higher score for aroma is nearly seven times higher than the odds of conventional maize having a higher score. Similarly, the odds of QPM having a higher score for texture in hand is three (the exponent of 1.1) times higher than the odds for CM. The results of the ordinal regression, as derived from the sign, size and significance of the coefficients, are very similar to those of comparing the means.

To test for the possible effect of the order of presentation, a binary variable was included to indicate whether the product was presented first (order = 1) or second (order = 0), but the coefficient was not found significant, indicating that the order of presentation did not affect consumers' acceptance of the food samples. Because only one QPM and one CM variety was included, the observed preference may be variety specific and may not necessarily be attributable to the quality protein trait. We can conclude, however, that this QPM variety is accepted and even preferred for most traits over this conventional maize variety for the preparation of *ugali*.

To analyze other factors that might influence consumer acceptance, the long model of Eqn (4) was estimated, containing both direct effects and cross-effects (Table 4). In the direct effects, the QPM variety has a significant positive effect for texture in hand, texture in mouth, and taste. The other significant direct effects were

Table 3. Consumer acceptance of QPM in Tanzania (short mixed-effect ordinal model, dependent variable is a nine-point Likert scale)

		Appearance		Aroma		Texture in hand		Texture in mouth[a]		Taste[a]		Overall[a]	
Analysis	Variable	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Comparing means	QPM	7.27	0.13	7.23	0.15	7.40	0.16	7.63	0.20	7.67	0.20	7.60	0.16
	CM	6.93	0.22	6.37	0.18	6.87	0.20	6.30	0.24	6.27	0.27	6.47	0.24
	Difference QPM − CM	0.33		0.87	***	0.53	*	1.33	***	1.40	***	1.13	***
Ordinal regression	QPM	0.78	0.51	1.90	0.55**	1.15	0.50*	2.01	0.53***	1.96	0.53***	1.93	0.54***
	Order (presented first)	−0.07	0.49	−0.57	0.49	0.50	0.48	−0.11	0.47	−0.09	0.48	0.46	0.47
	−2 Residual log pseudo-likelihood	846		1036		871		181[b]		170[b]		176[b]	
	n	60		60		60		60		59		60	

[a] Variance of random subject effect estimated at zero
[b] −2 log-likelihood
SE, standard error; QPM, quality protein maize; CM, conventional maize.
Asterisks indicate significance at: ***0.1%; **1%; *5%.

Table 4. Consumer acceptance of QPM in Tanzania (long mixed-effect ordinal model, dependent variable is a nine-point Likert scale)

		Appearance		Aroma		Texture in hand		Texture in mouth		Taste[a]		Overall	
Group	Variable	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Direct effects	QPM	0.00	2.77	2.78	2.72	6.00	2.79*	7.30	2.76*	6.45	3.04*	1.86	2.61
	Female	−2.25	1.01*	−1.50	0.89	0.71	0.96	−0.68	0.80	−0.19	0.79	−0.37	0.80
	Age (years)	0.06	0.05	−0.02	0.05	0.09	0.05	0.07	0.04	0.04	0.04	0.05	0.04
	Education (years)	−0.35	0.11**	−0.06	0.09	−0.13	0.10	−0.04	0.08	−0.08	0.08	−0.12	0.08
	Order (presented first)	0.37	0.54	−0.27	0.52	0.77	0.53	0.40	0.51	0.40	0.52	0.97	0.52
Cross effects	QPM × female	1.83	1.23	1.59	1.19	0.50	1.18	1.90	1.17	1.54	1.13	2.26	1.18
	QPM × age	−0.12	0.07	−0.03	0.06	−0.08	0.06	−0.11	0.06	−0.08	0.06	−0.05	0.06
	QPM × education	0.34	0.13*	0.01	0.12	−0.11	0.12	−0.07	0.11	−0.08	0.12	0.09	0.11
Model	−2 residual log pseudo-likelihood	985		999		955		1484		155[b]		1466	
	N	60		60		60		60		59		60	

[a] Variance of random subject effect estimated at zero.
[b] −2 log-likelihood.
SE, standard error; QPM, quality protein maize; CM, conventional maize.
Asterisks indicate significance at: ***0.1%; **1%; *5%.

gender and education on appearance, indicating that women generally scored the *ugali* lower for appearance, as did participants with higher education.

The interpretation of the direct effects in a model with cross-effects depends on the significance of the latter. Because the cross-effect QPM × female is not significant, the direct effect of gender relates to both QPM and CM. But since the cross-effect of QPM × education is significant and positive, the direct negative effect of education only applies to the reference category, conventional maize. So with increasing education, the odds that a respondent favorably rates the appearance of conventional maize decrease. To analyze the relationship between QPM and education, we have to add the direct effect (−0.35) to the cross-effect (+0.34) and that sum is not significantly different from zero, indicating that acceptance of QPM's appearance does not vary with education.

We conclude that participants in Tanzania scored the QPM *ugali* higher than CM *ugali* overall and for all specific characteristics. Consumer demographics played only a minor role: only education and gender had a significant effect, and then only on acceptance of appearance.

Kenya

In Kenya, two QPM varieties – KH631Q and WSQ104 – were compared to two conventional varieties – EMCO and H513 – in one urban and two rural settings, on a five-point scale. Despite the less precise scale, the answers were much better distributed than in Tanzania, where a nine-point scale was used. The categories with the highest number of answers were 'good' (36%) and 'fair' (33%), but evaluations were also received for the extremes 'very poor' (4%) and 'very good' (11%).

Because of the clear ordinal nature of the evaluation, only ordinal regression was used for the analysis. The results of the short model of Eqn (3) show that one QPM variety – KH631Q – was more appreciated than H513 (the omitted class in the regression), for taste, but otherwise there were no significant differences between the two (Table 5). The other QPM variety – WSQ104 – was more appreciated than H513 for appearance, texture and overall, but

Table 5. Consumer acceptance of QPM in Kenya (short mixed-effect ordinal model; dependent variable is a five-point Likert scale)

Variable	Value	Appearance		Texture[a]		Taste		Overall	
		Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Variety (ZH513 is the reference category)	EMCO (CM)	0.45	0.23	0.38	0.22	0.29	0.23	0.27	0.23
	KH631Q (QPM)	−0.01	0.23	0.40	0.23	0.52	0.23*	0.22	0.23
	WSQ104 (QPM)	0.61	0.23**	0.71	0.24**	0.37	0.23	0.47	0.23*
	H513 (CM)								
Location (Embu is reference category)	Itabua (rural women)	−0.26	0.28	−0.07	0.23	0.01	0.27	−0.34	0.26
	Mukuria (rural mixed)	−0.17	0.22	−0.03	0.18	−0.09	0.21	−0.43	0.20*
	Embu (urban)								
Order of evaluation (4th is the reference category)	1st	0.32	0.23	0.51	0.23*	0.54	0.23*	0.61	0.23**
	2nd	0.02	0.23	0.46	0.23*	0.11	0.22	0.15	0.23
	3rd	0.22	0.23	0.39	0.23	0.27	0.23	0.27	0.23
	4th								
Model	−2 Residual log pseudo-likelihood	7483		1460[b]		6924		7267	
	n	514		510		516		505	

[a] Variance of random subject effect estimated at zero.
[b] −2 log-likelihood.
SE, standard error; QPM, quality protein maize; CM, conventional maize.
Asterisks indicate significance at ***0.1%; **1%; *5%.

there was no difference for taste. Further, there were no significant differences between the two conventional varieties. The QPM varieties were never rated lower than CM varieties in one-on-one comparisons for any of the four criteria. However, there does not seem to be a systematic pattern in the acceptance of the two QPM varieties compared with the two CM varieties. This suggests that the greater acceptance of WSQ104 in general and KH631Q for taste may be due to characteristics specific to one or both of those varieties and may not be attributable to the quality protein trait. Regardless, the equal or greater preference of these varieties among Kenyan consumers indicates that these or related QPM varieties that also have good agronomic performance could be accepted and utilized in this target population.

The short model included binary variables for location and order. The location did not have a significant effect on consumer evaluation, except for the overall evaluation in one site – Mukuria – but order often did. For all criteria except appearance (for which all food samples could be evaluated simultaneously), consumers were likely to give higher acceptance ratings to those food samples that were evaluated first. As they did more evaluations, however, they became more critical and their scores decreased. This clearly illustrates the need to present food samples in random order in consumer acceptance studies.

To estimate the effect of demographic and educational variables, the long model with cross-effects (Eqn 4) was estimated. The results of the long model show effects of location, gender, age and education, but only for one variety: KH613Q (Table 6). This variety, compared to the control H513, is less appreciated in Itabua for appearance, texture and taste. This variety is, however, more appreciated by women in the overall evaluation, and more appreciated by older and more educated consumers in taste and overall evaluation.

We conclude that among the urban and rural consumers of Embu District QPM did not have any negative preferences, and that one QPM variety was generally better accepted over the two conventional varieties. The individual characteristics of varieties matter, however, and they differ between sites and with the socioeconomic characteristics of the consumers.

Ethiopia

In Ethiopia, the five-point scale was used, and the distribution of the scores was similar to that of Kenya. The scores with the highest proportion of responses were also ‘good’ (30%) and ‘fair’ (36%), with a similar proportion of ‘very poor’ (4%), although with a substantially higher proportion of ‘very good’ (24%). This distribution was similar across all criteria.

The results of the short ordinal regression show that Ethiopian consumers had a strong preference for *injera* made from *teff*, as indicated by the large and significant drop in acceptance when maize was mixed in the dough (Table 7). This drop was measured by the coefficient of the binary variable ‘maize’, indicating the use of a maize–*teff* mixture as compared to *injera* from pure *teff*, and was significant for all criteria, including overall evaluation, and independent of the maize proportion, either 50% or 80% (with 50% being the reference category). There was a substantial difference between the conventional varieties, however, with BH540 scoring significantly better than Melkassa 2 on all criteria, as shown by the significant coefficients for the variable BH540 and to be interpreted as the difference from the reference category for maize, Melkassa 2.

When QPM instead of conventional maize is substituted for *teff*, the drop in acceptance is less pronounced, as the significant coefficient for QPM shows. There is, however, a big difference between the two QPM varieties, and BHQP542 is substantially more appreciated than Melkassa 6Q. The last variety’s scores are actually similar to those of BH540. On the order of presentation, the results show that acceptance scores were significantly higher in the first round than in the second for the first two criteria of the evaluation: appearance and aroma. They were not significant for the other criteria, or for the order of presentation within the rounds. Still, it illustrates the importance of presenting food samples in random order.

To assess the effect of consumer demographics, those were added as factors in the long model (Table 8).The additional factors altered slightly the coefficient on the products, but not in a major way, and direct effects in a model with cross-effects need to be interpreted carefully, as discussed above. The results of the

Table 6. Consumer acceptance of QPM in Kenya (long mixed-effect ordinal model; dependent variable is a five-point Likert scale)

		Appearance		Texture[a]		Taste		Overall	
Variable	Value	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Variety (H513 is the reference category)	EMCO	0.24	1.61	0.59	1.62	0.02	1.57	0.23	1.62
	KH631Q	0.82	1.61	−1.42	1.62	−3.76	1.54*	−4.80	1.60**
	WSQ104	1.22	1.62	−2.85	1.73	−0.14	1.54	−1.97	1.60
Location (Embu is reference category)	Itabua	0.31	0.59	0.46	0.56	0.56	0.57	−0.14	0.58
	Mukuria	−0.57	0.54	−0.45	0.50	0.16	0.52	−0.64	0.52
Order (4 is the reference category)	1	0.50	0.26	0.58	0.25*	0.53	0.25*	0.66	0.26*
	2	−0.02	0.25	0.55	0.25*	0.15	0.25	0.12	0.25
	3	0.15	0.25	0.34	0.25	0.19	0.25	0.19	0.25
Female		0.04	0.52	−0.35	0.49	−0.69	0.49	−0.59	0.51
Age (years)		0.01	0.02	0.00	0.02	−0.01	0.02	−0.01	0.02
Education (years)		−0.03	0.06	−0.04	0.06	−0.06	0.06	−0.11	0.06
Variety × location (H513 and Embu are the references)	EMCO × Itabua	−0.84	0.79	−0.29	0.77	−0.86	0.77	−0.34	0.79
	KH631Q × Itabua	−1.82	0.79*	−1.80	0.78*	−1.54	0.77*	−0.85	0.79
	WSQ104 × Itabua	0.70	0.79	−0.21	0.81	−0.68	0.77	0.38	0.80
	EMCO × Mukuria	0.21	0.73	0.63	0.69	−0.77	0.69	0.35	0.71
	KH631Q × Mukuria	0.14	0.72	−0.16	0.69	0.02	0.70	0.29	0.72
	WSQ104 × Mukuria	0.40	0.71	0.48	0.73	−0.78	0.70	0.09	0.72
Variety × sex	EMCO × female	−0.10	0.68	−0.05	0.67	0.30	0.66	−0.09	0.69
(H513 and male are the references)	KH631Q × female	0.22	0.68	0.99	0.68	1.25	0.67	1.53	0.69*
	WSQ104 × female	0.65	0.69	1.57	0.71*	0.74	0.67	0.80	0.69
Variety × age	EMCO × age	0.00	0.02	−0.02	0.02	0.00	0.02	−0.01	0.02
(H513 is the reference)	KH631Q × age	−0.02	0.02	0.01	0.02	0.04	0.02*	0.04	0.02*
	WSQ104 × age	−0.03	0.02	0.03	0.02	0.01	0.02	0.01	0.02
Variety × education	EMCO × education	0.04	0.08	0.00	0.08	0.04	0.08	0.02	0.08
(H513 is the reference)	KH631Q × Education	0.01	0.08	0.09	0.08	0.21	0.08*	0.22	0.08**
	WSQ104 × Education	−0.01	0.08	0.10	0.08	0.01	0.08	0.13	0.08
Model	−2 residual log pseudo-likelihood	6773		1254[b]		6135		6371	
	N	447		442		448		437	

[a] Variance of random subject effect estimated at zero.
[b] −2 log-likelihood.
SE, standard error; QPM, quality protein maize; CM, conventional maize.
Asterisks indicate significance at: ***0.1%; **1%; *5%.

long model show that consumers with greater education are more critical in their evaluation: their scores are generally lower, as indicated by the negative coefficients. On the other hand, more educated participants have a slightly higher score for QPM varieties. Gender and age, on the other hand, did not show any significant effect on the sensory evaluation.

Factors affecting overall evaluation

Overall scores were analyzed by regressing the scores of the different criteria on the overall score, using a separate linear regression model for each country (Table 9). The value of a coefficient for a criterion can be interpreted as the contribution of the evaluation for that criterion to the overall evaluation . The results show that all evaluated sensory characteristics contributed to the overall evaluation, except for aroma and appearance of *ugali* in Tanzania. These last results are, however, likely affected by the small sample size.

Taste and texture were important to overall acceptance in all three countries, with taste being the biggest contributor to acceptance in Tanzania (0.43) and Ethiopia (0.34). In Kenya, taste was also important (0.26), but texture (0.34) and appearance (0.28) were more important. Appearance is important because *githeri* is a mixture of boiled maize and beans, and the maize kernels are clearly visible.

In Ethiopia, all other criteria apart from taste made a significant contribution to the overall acceptance, but the coefficients were relatively small: between 0.09 and 0.16. Here, the second most important criterion after taste was pliability (0.16), which is important because the *injera* is folded and used as a spoon to take the rest of the food to the mouth. This also explains why texture in both hand and mouth are the next most important criteria (0.15).

DISCUSSION

This study used a rigorous methodology to evaluate the acceptability of sensory characteristics of QPM varieties when used to prepare foods common in East African diets. The food products evaluated were *ugali*, a stiff porridge made from maize flour, in Tanzania; *githeri*, a mixture of boiled maize and beans, in Kenya; and *injera,* a pancake-like preparation made from fermented dough of *teff* flour, often mixed with maize or other cereals, in Ethiopia. The products were evaluated by urban, rural, male and female consumers with varying levels of education. The study established that African consumers can distinguish QPM products from their conventional counterparts in double-blind evaluations, contrary to conventional wisdom, and these distinct sensory characteristics should be acknowledged in promotion and dissemination

Table 7. Consumer acceptance of QPM in Ethiopia (short mixed-effect ordinal model; dependent variable is a five-point Likert scale; the general reference category is *teff*; within the mixtures it is 50% maize, within conventional maize it is Melkassa2 and within QPM it is Melkassa6Q)

	Appearance		Aroma		Pliability		Texture in hand		Texture in mouth		Taste		Overall	
Value	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Maize	−3.70	0.24***	−4.24	0.25***	−5.74	0.29***	−6.01	0.29***	−5.26	0.27***	−5.31	0.27***	−5.9	0.3***
BH540	1.20	0.24***	0.73	0.24	0.93	0.24***	1.39	0.25***	0.54	0.24*	1.08	0.24***	0.8	0.2***
Maize at 80%	0.43	0.24	−0.08	0.24	−0.19	0.24	0.07	0.24	0.15	0.24	0.19	0.24	0.0	0.2
BH540 at 80%	−0.05	0.34	0.00	0.34	0.52	0.34	0.25	0.34	−0.02	0.34	−0.19	0.34	0.3	0.3
QPM	0.31	0.24	0.49	0.24*	0.77	0.24**	0.87	0.24***	0.66	0.24**	0.77	0.24**	0.7	0.2**
BHQP542	1.41	0.24***	1.40	0.25***	1.73	0.25***	2.07	0.25***	1.70	0.25***	1.40	0.25***	2.1	0.3***
QPM at 80%	−0.37	0.34	0.04	0.34	−0.13	0.34	−0.30	0.34	0.03	0.34	−0.26	0.34	−0.1	0.3
BHQP542 at 80%	−0.26	0.34	0.27	0.35	0.14	0.35	−0.12	0.35	−0.58	0.34	−0.11	0.34	−0.5	0.4
1	0.28	0.11*	0.31	0.11**	0.10	0.12	0.22	0.12	0.19	0.11	0.18	0.11	0.1	0.1
1	0.03	0.18	−0.11	0.18	0.24	0.18	0.31	0.18	−0.02	0.18	−0.16	0.18	0.0	0.2
2	0.07	0.18	−0.05	0.18	−0.14	0.18	0.13	0.18	−0.04	0.18	−0.01	0.18	0.1	0.2
3	−0.06	0.17	0.08	0.18	0.13	0.18	0.16	0.18	0.07	0.18	−0.03	0.18	0.1	0.2
4	0.03	0.18	0.07	0.18	0.05	0.18	0.15	0.18	0.04	0.18	0.04	0.18	0.0	0.2
−2 residual log pseudo-likelihood	20760		22991		40039		30661		20784		27754		24895	
N	1199		1200		1200		1200		1200		1199		1200	

SE, standard error; QPM, quality protein maize; CM, conventional maize.
Asterisks indicate significance at ***0.1%; **1%; *5%.

activities. While early experience with *opaque-2* maize led to a widely held belief that any difference in the sensory characteristics of these biofortified varieties would lead to their rejection by consumers, this study indicates that the quality protein trait can result in sensory changes that are preferred by consumers in East Africa.

In all three countries, consumers found QPM acceptable and even preferable to conventional maize for the preparation of widely consumed foods. This indicates that if QPM grain were accessible, it could be widely used by consumers, enabling the biofortified crop to have a positive impact in at-risk populations, in particular those with poor-quality protein intake and lysine deficiency, commonly associated with cereal-based diets.[42] The study did, however, find substantial differences in consumer acceptance among maize varieties, between conventional and QPM varieties as well as between varieties within each group. It is therefore important to have new varieties carefully tested by consumers and to avoid over-generalization. Furthermore, as impact is determined by both farmer adoption and consumer acceptance, QPM varieties must have competitive agronomic as well as consumer characteristics.

In Tanzania, only one QPM and one conventional variety were evaluated, in an urban setting, and these varieties were of very different genetic backgrounds. The QPM variety was clearly more appreciated than the conventional one, but other varietal differences could have played a role. In Kenya, four varieties were tested, of which two were QPM. One QPM variety was well evaluated, but not the other. Again, the varieties were from different backgrounds, so the effect of the QPM trait and that of other varietal characteristics were hard to distinguish. In Ethiopia, similarly, two conventional and two QPM varieties were tested. While QPM varieties were, on average, more appreciated, there was a substantial difference between the conventional as well as between the QPM varieties, with the better conventional variety appreciated similarly to the lesser QPM variety. While the findings were generally consistent across countries and demographic groups, none of the tests strictly isolated the QPM trait and therefore the greater acceptance of QPM varieties may still be due to other varietal differences. To isolate the QPM trait, pairs of near-isogenic varieties should be tested. This should be possible given the common practice of converting existing varieties into QPM by backcrossing.[16]

Further, in Ethiopia, *injera* from pure *teff* was much more appreciated than *injera* from maize of any variety. However, *injera* with QPM in a 50/50 mixture with *teff* was generally more appreciated than *injera* with conventional maize in the same ratio. Therefore, for the same level of acceptance, more QPM can be added, reducing the need for the more expensive *teff* and thereby reducing the overall cost of *injera*. In mixtures of 80% maize, however, the advantage of QPM disappears, indicating the need for further research to evaluate *injera* with lower levels of maize in the mixture. A study of current practices in mixing *injera* flour with different cereals in different areas of Ethiopia could provide guidelines for such studies.

Methodologically, this study shows that affective tests are easy and inexpensive to conduct in central locations with African consumers. However, one of the study's limitations is that it selected volunteers rather than individuals randomly drawn from the target population. These studies were the start of a wider range of studies to develop and test methods for consumer acceptance with the ultimate target audience: rural consumers. The experience with these studies indicates that this method, initially started with urban consumers and later expanded and adapted to rural consumers, is convenient and effective for both groups, and for educated as well as illiterate consumers. This was confirmed subsequently by a larger study with rural consumers in Tanzania (which will be reported elsewhere) and, based on this experience, the method is currently being applied with rural consumers in Ethiopia.

While we do not claim the participants in this study were representative in a statistical sense, we do not think their opinion differs much from rural consumers, although this needs to be documented. While staff at the agricultural research center in Tanzania were likely aware of QPM, very few participants in Kenya

Table 8. Consumer acceptance of QPM in Ethiopia (long mixed-effect ordinal model; dependent variable is a five-point Likert scale)

		Appearance		Aroma		Pliability		Texture in hand		Texture in mouth		Taste		Overall	
Variable	Value	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Maize (Melkassa 2 is the reference)	Maize	−3.74	0.24***	−4.28	0.25***	−5.79	0.29***	−6.07	0.29***	−5.31	0.27***	−5.36	0.27***	−5.4	0.3***
	BH540	1.22	0.24***	0.73	0.24**	0.94	0.24***	1.41	0.25***	0.55	0.24*	1.09	0.24***	1.1	0.2***
	Maize at 80%	0.44	0.24	−0.09	0.24	−0.21	0.24	0.07	0.24	0.15	0.24	0.19	0.24	0.2	0.2
	BH540 at 80%	−0.06	0.34	0.01	0.34	0.53	0.34	0.25	0.35	−0.03	0.34	−0.19	0.34	−0.2	0.3
QPM (Melkassa 6Q is the reference)	QPM	−1.16	0.58*	0.90	0.59	1.34	0.60*	0.33	0.60	0.65	0.59	0.36	0.59	0.4	0.6
	BHQP542	1.43	0.24***	1.40	0.25***	1.74	0.25***	2.08	0.25***	1.71	0.25***	1.40	0.25***	1.4	0.2***
	QPM at 80%	−0.40	0.34	0.05	0.34	−0.11	0.34	−0.30	0.34	0.03	0.34	−0.26	0.34	−0.3	0.3
	BHQP542 at 80%	−0.24	0.34	0.27	0.35	0.14	0.35	−0.12	0.35	−0.59	0.34	−0.11	0.34	−0.1	0.3
Round	1	0.27	0.11*	0.33	0.11**	0.11	0.12	0.23	0.12*	0.20	0.11	0.18	0.11	0.2	0.1
Order of presentation	1	0.01	0.18	−0.14	0.18	0.23	0.18	0.29	0.18	−0.04	0.18	−0.19	0.18	−0.2	0.2
	2	0.06	0.18	−0.07	0.18	−0.16	0.18	0.11	0.18	−0.06	0.18	−0.02	0.18	0.0	0.2
	3	−0.07	0.18	0.10	0.18	0.15	0.18	0.17	0.18	0.08	0.18	−0.04	0.18	0.0	0.2
	4	−0.01	0.18	0.05	0.18	0.05	0.18	0.13	0.18	0.02	0.18	0.01	0.18	0.0	0.2
Sex	Female	0.10	0.24	0.41	0.27	−0.10	0.27	−0.12	0.29	−0.01	0.28	0.11	0.31	0.1	0.3
Age (years)		0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.01	0.02	0.0	0.0
Education (years)		−0.04	0.02*	−0.08	0.02**	−0.05	0.02*	−0.06	0.03*	−0.07	0.02**	−0.08	0.03**	−0.1	0.0***
Interactions	QPM × female	−0.10	0.23	−0.07	0.23	−0.03	0.24	0.06	0.24	−0.18	0.23	−0.36	0.23	−0.4	0.2
	QPM × age	0.03	0.01*	−0.02	0.01	−0.02	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.0	0.0
	QPM × education	0.05	0.02*	0.02	0.02	0.01	0.02	0.04	0.02*	0.02	0.02	0.03	0.02	0.0	0.0**
Model	−2 residual log pseudo-likelihood	21045		23454		43955		30990		20934		27836		25261	
	N	1199		1200		1200		1200		1200		1199		1200	

Asterisks indicate significance at ***0.1%; **1%; *5%.
SE, Standard error; QPM, quality protein maize; CM, conventional maize.

Table 9. Effect of the scores for specific criteria on the overall evaluation score (using ordinary least squares regression)

	Tanzania (*ugali*)		Kenya (*githeri*)		Ethiopia (*injera*)	
Criteria	Coeff.	SE	Coeff.	SE	Coeff.	SE
(Intercept)	0.03	0.82	0.49	0.12***	0.20	0.06***
Appearance	−0.02	0.10	0.28	0.04***	0.09	0.02***
Aroma	0.17	0.11	–	–	0.10	0.02***
Pliability	–	–	–	–	0.16	0.02***
Texture	–	–	0.34	0.03***	–	–
Texture in hand	0.24	0.11***	–	–	0.15	0.03***
Texture in mouth	0.19	0.10	–	–	0.15	0.03***
Taste	0.43	0.10***	0.26	0.03***	0.34	0.02***
R^2	0.74		0.57		0.79	
N	60		485		1198	

Asterisks indicate significance at n ***0.1%; **1%; *5%.

and Ethiopia would have been aware. In any case, stringent measures for double blind testing were applied, so this should not influence the test results.

While our study shows how affective tests can be used with African consumers, they should use the proper methodology, in particular double-blinding, which is generally incompatible with promotional demonstrations and should, therefore, be organized separately. Further, the experience of this study indicates that the nine-point scale is convenient with urban, educated consumers, although they almost uniquely used the top five categories only. While the nine-point scale provides a finer resolution than the five-point scale, the sample size ($n = 30$) was likely too small to distinguish small differences in this evaluation. The five-point scale was convenient for rural and less-educated consumers, as it can easily be used on any criterion in any language. As this scale has lower resolution, it needs a larger sample size than a nine-point scale. In this study, however, the responses were well distributed over the scale, and the sample sizes (131 and 120) were large enough to find significant differences for almost all criteria. This scale should be analyzed with ordinal regression, which is relatively straightforward with modern statistical software. However, consumer evaluations typically involve comparisons of several products by the same person, and those are likely to be correlated. Therefore, the analytical model should account for within-person correlation, for example, through the inclusion of a random subject effect. As more biofortified crops and other agricultural technologies and food products are developed to improve the nutrition and health of vulnerable populations, methodological development and practice for sensory evaluation and affective tests will be increasingly important.

In this study, we used the terms ‘good’ and ‘bad’ as convenient indicators of quality.[30] The terms ‘like’ and ‘dislike’ are, however, more commonly used in consumer acceptance studies and affective tests.[22] These terms fully embrace the subjective nature of the evaluation in affective tests, as compared with the attempt at objective quality evaluation in sensory evaluation, and should therefore be considered in this type of studies.

In the future, the method tested here needs to be further applied in rural areas. Subsequent studies have already been conducted with rural consumers in Tanzania and are planned with mothers and children in rural Ethiopia. Also, it would be interesting to include an assessment of consumers' willingness to pay for the new products, in particular QPM flour or grain.

Although this study shows that consumers can distinguish QPM from conventional maize in a range of criteria, it is not clear what chemical or mechanical properties cause that distinction. More laboratory research is therefore indicated to establish these relationships, for example, on the relationship between taste and texture on the one hand, and protein or starch composition and mechanical cohesion on the other. Once these relationships are established using near-isogenic QPM–CM pairs, laboratory tests of new varieties can reduce the more costly field and consumer research. Because African consumers, as do their counterparts in many developing countries, typically eat with their hands, the criterion of texture in the hand should be paid special attention.

This study was limited to urban consumers in Tanzania and Ethiopia, and we did not find a difference between urban and rural consumers' preferences in Kenya. In Tanzania, a follow-up study has now been conducted with rural consumers (the results of which will be presented elsewhere), which indicated no difference in acceptance with the urban population. In Ethiopia, acceptance studies with rural consumers, including children, are currently taking place. Although the consumers in our study showed a good acceptance of QPM, this does not necessarily translate into willingness to pay a premium. In the Tanzania follow-up study, therefore, consumers' willingness to pay was also estimated using an economic experiment. Preliminary results indicate that willingness to pay for QPM was positive, and the premium was positively correlated with their consumer acceptance score. Similar results were found in Ghana in a study on consumer acceptance of orange maize, biofortified with provitamin A carotenoids.[43] Generally, while consumers seek convenient and healthy products, taste is consistently rated as the most important factor that drives consumption and repeat purchase of consumers.[44,45] These results lead us to believe there is a market for QPM grain in East Africa. Finally, the current study was done with adults only, whereas the major target audience are children. Therefore, the study should be repeated with infants and children, as is already planned in Ethiopia.

We conclude that common African maize food products made from QPM can often be distinguished from those made from CM, and are appreciated by African consumers. Moreover, in Ethiopia, use of QPM allows for a higher rate of substitution for the more expensive *teff*, reducing the cost of *injera*, the major food preparation. These positive factors can and should be exploited in the promotion of QPM, along with messages on its nutritional benefits.

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SUPPORTING INFORMATION

Supporting information may be found in the online version of this article.

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