

Full Length Research Paper

Improving the nutritional value of conventional food with underutilized leafy vegetables - consumers' acceptance of combining porridge with cowpea leaf powder

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Reaching the second UN Sustainable Development Goal requires improving the nutritional value of food products and dietary diversity. Simultaneously, recent research highlights the importance of processing highly nutritious but underutilized African leafy vegetables (ALV) for lowering post-harvest losses and bridging off-season gaps. Combining both goals, it seems promising to utilize neglected ALV for enhancing conventional food items that are already well accepted in consumer diets but low in nutritional value. Therefore, this study analyzes consumer demand for maize (*Zea mays* L.) and millet (*Eleusine coracana* (L.) Gaertn) porridges combined with cowpea leaf powder (*Vigna unguiculata* L.Walp) (CLP) in Kayunga, Uganda. The study relies on combining sensory analysis with a binding Becker-DeGroot-Marschak auction to analyze consumer demand. Results show that consumer acceptance of CLP-enhanced porridges is predominantly shaped by sensory perception ($p < 0.05$). Although adding CLP lowers consumers' sensory appreciation, the study still identifies a reasonably large group of consumers, nearly 50% of the participants, who valued CLP-enhanced porridges as much as plain ones. This justifies the conclusion that adding CLP is not without risks but is accepted among many consumers and can thus help to promote the consumption of locally available plants. For future product development, we recommend that priority is given to sensory attributes, and special focus is placed on consumers who barely incorporate fresh vegetables into their diets.

Key words: African leafy vegetables, Uganda, willingness to pay, sensory analysis, porridge.

INTRODUCTION

Micronutrient deficiencies in East Africa remain worrisome. More than 30% of the population suffers from an insufficient intake of vitamins and minerals (FAO, 2020). Recently, researchers worldwide have acknowledged the importance of micronutrient supply,

suggesting the relevance of dietary quality instead of plain caloric intake (Miller et al., 2020). Inadequate dietary quality is among the primary causes of a wide number of health issues ranging from cardiovascular diseases to diabetes and death. Poor dietary quality

frequently corresponds with low intake of fruits and vegetables, which is among the leading dietary risk factor (GBD 2017 Diet Collaborators, 2019). Significant challenges for dietary quality, especially in the form of adequate dietary diversity, often arise due to insufficient accessibility that disproportionately affects less-developed parts of the world (FAO, 2020). Furthermore, the globally recognized nutrition transition caused diets to shift toward processed foods (Reardon et al., 2021). Since processed food products are often rich in sugar and salt and low in nutrients (Reardon et al., 2021), this shift has induced severe health challenges such as obesity.

Against this backdrop, research needs to highlight pathways for product development towards more nutrient-rich food items that consumers can add to their diets, thereby increasing both the nutritional value of foods consumed and the diversity of their diets. In order to achieve these goals, the relevant food items need to be accessible and affordable, and feature the main qualities consumers' desire, such as quick and easy preparation. Above all, the food items must have attractive sensory characteristics, as nutritional interventions in food are only promising if consumers accept the foods sensory characteristics (Boateng et al., 2019). This is why it is especially promising to create nutrient-rich food items by enhancing conventional products with more nutrient rich components.

The research presented in this paper reflected this approach. It addressed both nutritional quality and dietary diversity, and analyzed the potential of enhancing consumers' diets through newly developed food items based on enhancement with locally available but underutilized African Leafy Vegetables (ALV). So far, hundreds of ALV grown throughout Africa have gained little attention, despite their excellent nutritional value (Aworh, 2018). Recent literature, however, has highlighted the potential of ALV in addressing micronutrient deficiencies (Maseko et al., 2019). Ochieng et al. (2018) have found that increases in promotion and demand of ALV in a given community increase dietary diversity for women and children under the age of five years. What is more, ALV are valued for their better resistance to pests, diseases, and harsh weather conditions and are often the cheapest source of essential vitamins and minerals, as compared to exotic crops (Aworh, 2018; Bua and Onang, 2017).

It is mostly the lack of awareness of health benefits, lack of knowledge of preparation techniques, and off-season gaps that impede sufficient utilization (Bua and Onang, 2017). Short shelf-lives of only up to two days

constitute additional challenges, leading to farmers experiencing losses between 10 and 50 % of their harvest (Gogo et al., 2018). This aspect, however, makes the approach of enhancing conventional food items with ALV components appear even more promising. Such enhancement, contrary to direct marketing of recently harvested ALV, would imply the use of ALV components in more durable conditions (e.g., dried or pulverized). Thus, the utilization of locally available ALV in conventional food products would not only improve the nutritional value of the food items consumed, but also would help reduce post-harvest losses. Yet, evidence of consumers' perception of and preferences for conventional products enhanced with ALV in East Africa is still scarce.

Barugahara et al. (2015), however, found that fermented millet porridge combined with *Moringa oleifera* leaves (Lam.) (part of the ALV family) was accepted among children and mothers in Western Uganda and could be part of a solution of tackling malnutrition. In addition, research on attitudes towards healthy foods in similar contexts supports this optimistic claim. De Groote et al. (2020) identified a potential market for improved cereal products in Kenya and Wanyama et al. (2019) found that poor consumers might welcome foods that are micronutrient-fortified or include new types of nutritious ingredients.

Contributing towards closing the research gap on consumers' perception of and preferences for conventional products enhanced with ALV in East Africa, the present study analyzed consumer demand for traditional porridges combined with ALV component of cowpea leaf powder (CLP). The motivation of this study was to test whether combining soft porridge with cowpea leaves could be a practical approach to introducing nutrition-rich vegetables in East African diets, thereby tackling malnutrition by addressing micronutrient deficiencies. The choice of CLP-enhanced porridge builds on two main reasons. First, porridge is an affordable food frequently consumed by the vast majority of the Ugandan rural population. Its preparation is quick and easy. At the same time, porridges are often solely made out of maize or millet, and lack minerals and vitamins (Ndagire et al., 2015). Second, cowpea leaves provide great nutritional value, and are widely available throughout Uganda (Okonya and Maass, 2014). They are rich in minerals and vitamins, and can provide the recommended daily intake of many health essential nutrients, such as iron, calcium, phosphorus, and magnesium (Enyiukwu et al., 2018). Nevertheless, cowpea leaves are being underutilized, with seasonality

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and inadequate post-harvest handling techniques being among the major challenges. Evidence from Kenya shows that while cowpea leaves are consumed during the season in which cowpeas are produced consumption declines during the off-season (Owade et al., 2020). This highlights the importance of preserving cowpea leaves adequately to bridge off-season gaps.

The objectives of the study were: (1) to assess consumers' demand for maize and millet porridges enhanced with CLP relative to plain porridges using willingness to pay (WTP) auction and sensory perception; and (2) to identify factors influencing consumers' acceptance.

CONCEPTUAL FRAMEWORK

At the outset, we consider how porridges enhanced with CLP align to food preferences among the Ugandan rural population in general. Uganda is in an early stage of a dietary transition that will probably result in health implications (Auma et al., 2019). As in other East African rural communities, about 43% of the food consumed is purchased, with processed and ultra-processed foods making up 70% of all purchases (Reardon et al., 2021). Minimally processed foods such as flour, dried fish, or packaged milk are foods with only a little modification, such as cleaning, drying, or grinding. Ultra-processed foods such as canned sodas or cookies are highly processed products with added salt, sugar, or oil (Reardon et al., 2021). Maize and millet porridges are ultra-processed foods with low nutritional value beyond calories. A study on dietary patterns in rural Uganda found that the consumption of processed diets is among the two major dietary habits of middle aged (39 ± 13 years) men and women. This included high consumption of salad dressing, cold cuts, and sweets. A closer look at food groups being consumed showed mean daily servings of cereals, starchy roots, and plantains were highest (Holmes et al., 2018). Kiguli et al. (2019) found that consumers' food choices in rural Eastern Uganda were predominantly based on availability and local accessibility. There was a particular lack of food diversity during the dry season, and people depended on a few staple foods, such as maize flour, daily. Moreover, a study on pre-cooked beans showed that consumers value nutritious products that are quick to prepare (Aseete et al., 2018). Combining conventional porridges with CLP fits into the current demand for more processed and nutritious foods. Adding CLP is an option to increase dietary diversity during the off-season.

METHODS

Study site and participants

The survey aimed to analyze rural consumers' demand for porridge

combined with locally available cowpea leaves. The cowpea leaves were freshly bought from open markets in Kampala, dried and ground, and thus minimally processed. Maize and millet powder were bought from supermarkets in Kampala. We obtained research permission and ethical clearance from the Uganda National Council for Science and Technology and the Makerere University School of Health Sciences Institutional Review Board. The survey was conducted in the Kayunga district of Uganda from February to March 2020. The Kayunga district is a rural area that lies in the North Central part of the country. The prevalence of anemia is around 31% for women and 14% for men, with about 30% of women and 12% of men being overweight or obese (Uganda Bureau of Statistics, 2018). Dietary diversity is lower among rural women than men. Their diet comprises of high fat intake along traditional dietary patterns (Auma et al., 2019). Due to their relatively high prevalence of anemia and lower dietary diversity, and because they are often responsible for food preparation, our main interest was women. However, since food is traditionally prepared for the whole family, we did not completely exclude men from the survey. Cowpea leaves are typical in the area of the study site and are predominantly grown on a small scale. We targeted participants at point-of-purchase at open markets in Kayunga Town, Busaana, Kangulumira, and Nazigo that were open on different weekdays. A pilot study was conducted at a different market in the same location to test the setup of the survey. As the markets were some kilometers apart (> 20 km), it is unlikely that the same participant visited different markets and got selected twice. Participants were screened for the following characteristics to participate in the survey: They had to be at least 18 years old, free of diabetes and food sensitivities, responsible for food purchasing decisions in the household, and interested in testing the target products. Approaching participants at open markets allowed us to question many of them easily. We avoided conducting the same study more than once per market. This allowed us to ensure that participants were not interviewed twice and were thus not already informed about the products by friends or family. We used convenience sampling that included if participants had time to take place in the survey. Participants were approached when entering the market. If they did not meet the qualification criteria the next person entering the market was approached. Approximately 30 participants were questioned per market. The questioning per participant, including the sensory analysis and WTP auction took about 20 minutes. Thus, we spent five to six hours at each market. This allowed us to question participants during different day times (morning, noon, afternoon). The drying of the cowpea leaves and thus, preparation of approximately 400 flour bags was time and resource intensive. The availability limited our sample size, which is therefore rather small. However, it is still sufficient for studying preferences for the enriched porridges. In total, 126 people participated in the survey. Due to incomplete questionnaires, we excluded 24 participants from further analysis. Participants agreeing to participate in the survey were informed about their right to leave the survey at any time, asked to give their written consent, and paid 2000 Ugandan shillings (UGX) (4000 UGX = 1 U.S. dollar at the time of the survey) as an expression of our gratitude for their time and to ensure they had the financial means to participate in the WTP experiment.

Products

We asked each participant to taste four different porridges: millet porridge, millet porridge combined with CLP, maize porridge, and maize porridge combined with CLP (Figure 1). The CLP made up 20% of both mixed porridge types, respectively. The rate was defined after running pre-tests on consumer acceptance of different ratios. The products were developed by nutrition specialists of



Figure 1. Four different porridges: Millet porridge (O), Millet porridge mixed with CLP (⬠), Maize porridge (Δ), Maize porridge mixed with CLP (□).

Makerere University in Kampala, Uganda. Owing to the nutrients found in the CLP namely zinc, vitamin A and iron their consumption is associated with improved satiety, good immunity, proper digestion, and proper eyesight. The porridges were prepared in traditional way each morning by experienced cooks from our team. Specifically, 60 g of each porridge were mixed with 150 ml cold water; 300 ml boiling water were added to the two millet porridges and 400 ml boiling water were added to the two maize porridges. The two millet porridges were boiled for two to three minutes, and the two maize porridges were boiled for 30 minutes. As porridge is preferred sweet in the area, 25 g of sugar were added to each mixture. To keep the porridges warm for consumption, they were stored in thermo flasks.

Sensory analysis

Tents were used to conduct the survey. This allowed us to shield survey participants and gave them the opportunity to sit down and taste the products in quiet. Each participant was questioned by two enumerators to ensure double-blind testing. The first enumerator asked sociodemographic questions and conducted the sensory analysis. Survey participants received approximately 10 g of each cooked porridge in plastic cups. The amount equaled about three normal mouthfuls of the product, which was presumed to be sufficient to rate the sensory attributes. As we labeled each porridge with either a triangle, circle, square, or pentagon, neither the enumerator nor the participant knew which porridge was inside which cup. The order was randomized to avoid first-sample bias. Participants were asked to rate one porridge at a time. They were not allowed to go back and re-taste samples. Sensory characteristics considered included color, aroma, texture in the mouth, taste, and general appearance. Participants were asked to rate each attribute on a five-point Likert scale ranging from 1 = dislike it very much, 2 = dislike it, 3 = neither like nor dislike it, 4 = like it, 5 = like it very much. The five-point Likert scale has been used in previous studies and was demonstrated to be understandable among less educated consumers (De Groote et al., 2018). The answers were immediately entered onto electronic tablets by the enumerators. Participants were asked to rinse their mouths with water after consuming each product.

Willingness to pay

After finishing the sensory analysis, a second enumerator conducted the WTP using Becker-DeGroot-Marschak (BDM) auction. The BDM is non-theoretical, can be performed individually, and can be implemented at open markets. It has already been applied in several studies assessing consumers' WTP in Africa, and has been easily understood by less-educated participants (De Groote et al., 2018, 2020). The four porridges were shown to the

participant in dried form, packaged in transparent plastic bags. Each bag contained 60 g of the dry porridge powder. The porridges were presented in the same randomized order and labeled with the same symbols as in the sensory analysis. The order differed among the participants. The participants were asked to state their WTP for each of the products. The enumerator wrote down their statements. To prevent participants from having to buy all four products, the statement for one product only was randomly chosen as binding. Each participant then drew a number from a basket, which was compared to the price stated for the binding product. If the drawn number was below or equal to the WTP indicated by the participant, they had to buy the product at the random price using their own money. If the randomly drawn number was higher than the stated WTP, the participant had no chance to buy the product. The random distribution ranged around the expected WTP for one porridge, thus from number 100 to 1000. The procedure was described to the participants in detail, and follow-up questions had to be answered correctly. The enumerator informed every second participant about the ingredients of the porridges and their nutritional benefits. While the explanation of the plain porridges contained information about their bodybuilding and energy benefits, the explanation of the porridges combined with CLP contained further information about their contributions to good immunity, proper digestion, and proper eyesight. We assumed there are no systematic differences between the two groups, although we found tendencies in the color perception (Supplementary Table 1). After finishing the WTP experiment, participants were questioned on their general consumption and shopping behavior.

Statistical model

We applied structural equation modeling (SEM) using Stata to determine linkages between participant characteristics and their WTP, using maximum likelihood estimation. The SEM connects linear regression and factor analysis and, in general, analyzes variance-covariance structures (Aichholzer, 2017). Further, the model allowed us to use the response variable of one regression as a predictor in another regression. Figure 2 shows an exemplary SEM. Rectangles represent observed variables, and circles containing ϵ represent error terms. Arrows indicate hypothesized direct effect on endogenous variables. The SEM shows the sum of all assumed structural equations:

$$y_1 = \alpha_1 + \gamma_{11}x_1 + \epsilon_1 \quad (1)$$

$$y_2 = \alpha_2 + \gamma_{21}x_1 + \beta_{12}y_1 + \epsilon_2 \quad (2)$$

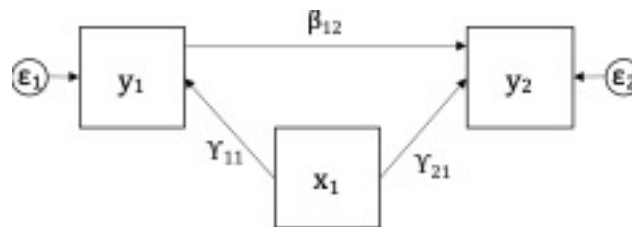
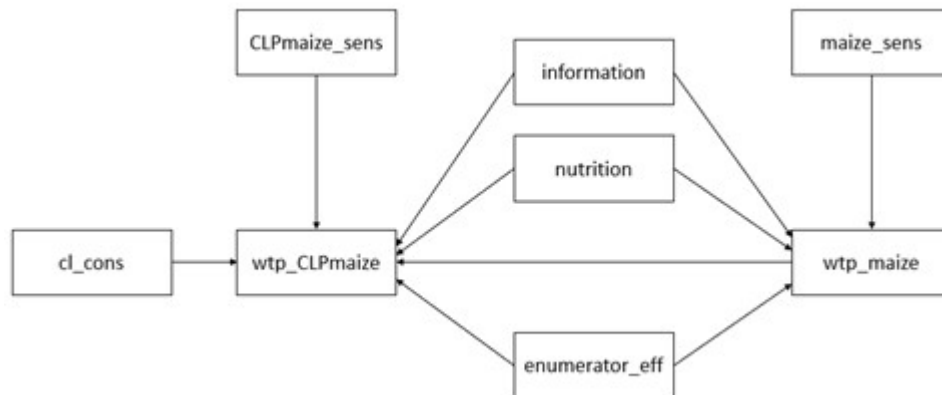
Variable selection

We estimated one SEM for the millet porridges and one for the

Table 1. Results of the factor analysis on sensory perception of the porridges.

Characteristic ¹	Factor loading			
	Millet	CLP_millet	Maize	CLP_maize
Color	0.70	0.70	0.73	0.59
Aroma	0.71	0.84	0.73	0.81
Texture in the mouth	0.62	0.83	0.85	0.81
Taste	0.74	0.86	0.83	0.84
General appearance	0.78	0.86	0.83	0.87
Cronbach's- α	0.74	0.88	0.85	0.84
KMO	0.77	0.84	0.78	0.83

¹5-point Likert scale ranging from 1 = dislike it very much to 5 = like it very much.

**Figure 2.** Exemplary SEM.**Figure 3.** SEM for WTP for maize porridge and maize porridge combined with CLP. cl_cons = frequency of cowpea leaf consumption, sens=sensory perception (factor).

maize porridges. Figure 3 shows the model for the maize porridge. Within both SEMs, we ran two equations, one for the plain porridge and one for the porridge combined with CLP. The plain porridge was also included as a predictor in the regression for the combined porridge. One directly observed variable was used as a predictor, namely whether the participant received additional *information* (binary) about the products. Additionally, we added *frequency of cowpea leaf consumption* in the regressions of the combined porridges. Frequency of cowpea leaf consumption categorically ranged from 0 = never, 1 = 1 to 3 times per month, 2 = 1 to 3 times per week (regularly), 3 = 4 to 7 times per week (frequently). Besides directly observable variables, *nutrition awareness* and the *sensory*

perception of each porridge were added as factor variables. To obtain the factors, we ran a principal component factor analysis with varimax rotation. We found that the sensory characteristics of each porridge loaded on one factor, respectively (Table 1). Additionally, we found that six nutrition statements loaded on one factor (Table 2). The sampling adequacy was determined via Bartlett's test and the Kaiser-Meyer-Olkin (KMO) criterion. The internal consistency was determined via Cronbach's- α . KMO values above 0.6 and Cronbach's- α values above 0.5 were considered acceptable. The Cronbach's- α for the sensory characteristic's factors ranged between 0.74 and 0.88, with KMO values ranging between 0.77 and 0.84. The Cronbach's- α for the nutrition awareness factor was

Table 2. Results of the factor analysis on dietary behavior.

Nutrition awareness ¹	Factor loading
I am eating enough vegetables for good health.	0.54
I compare labels to select the most nutritious food.	0.79
I usually look for health information when I buy food products.	0.61
When at the market I look for food that supports the prevention of diseases.	0.64
When at the market I look for food that supports a strong immune system.	0.78
When at the market I look for food that supports good eyesight.	0.60
Cronbach's- α	0.74
KMO	0.77

¹5-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree.

0.75 and the KMO 0.78. The enumerator effect was included as a control variable. The error term was robust and clustered at market level. To determine the robustness of the model we reran the calculation including age in years, being female, and education in years.

RESULTS

Participant characteristics

Participants had an average age of about 37 years, were mainly female (72%), and received 7.5 years of formal education (Table 3). On average, participants lived in households comprising of five people. Moreover, 26% of the participants were married and 67% of the participants consumed millet porridge as their main porridge, while the remaining 33% consumed maize porridge as their main porridge. The majority (79%) of the participants had children between 6 and 59 months. Most participants consumed porridge frequently (4 to 7 times per week) or regularly (1 to 3 times per week). This confirms our assumption that porridge is widely consumed in the area and thus, suitable for nutrition intervention. Concerning nutrition awareness, we found a tendency that participants tended to agree with the statements we presented, with mean values above 3. The statements “I am eating enough vegetables for good health” and “When at the market I look for food that supports a strong immune system” received the highest agreement with mean values of 3.96 and 3.92, respectively. The findings suggest that the participants are on average rather conscious about healthy nutrition. This contrasts the assumption that nutrition awareness is low. Still, the results are heterogenous, as up to 30% of the participants rated the statements below 3 “neither like nor dislike it”.

Sensory analysis and WTP

The mean sensory scores were highest for the plain

millet porridge in all five characteristics (Table 4). These differences were found to be statistically significant, except for the taste in maize. Sensory scores for the porridges combined with CLP received statistically significantly lower scores than their plain porridge counterpart in all characteristics. Millet porridge combined with CLP received statistically significantly higher scores than maize porridge combined with CLP for color and texture in the mouth. Although on average the plain porridges were rated higher than the combined porridges, we found that 40 to 50% of the participants rated the combined porridges at least as high as the plain ones. The mean WTP was highest for plain millet porridge (0.26 US\$). This price was significantly higher than the average for the remaining porridges. About 50% of the participants were willing to pay an equally high price for the combined porridges compared to the plain porridges. The distribution of WTP is shown in Supplementary Figure 1.

Structural equation model

Table 5 presents the results obtained from SEM for the millet and maize porridges. Information about the ingredients and health benefits significantly increased participants' WTP for the plain and combined millet porridge. Additionally, participants with a higher nutritional awareness were willing to pay more for the plain millet porridge. Moreover, a higher WTP for both combined porridges is in line with a higher sensory perception and a higher frequency of cowpea leaf consumption of the products. To check for the robustness of the findings, we reran the model with control variables. These variables included age, being female, and education (Supplementary Table 2). We observed the same trends. Based on these findings, we took a deeper look into differences in sociodemographic and sensory perception. We compared these factors between a) participants who were willing to pay a price for the

Table 3. Participant characteristics and consumption frequencies.

Characteristics	Mean	SD	Min.	Max.
Sociodemographic				
Age (years)	36.76	12.73	18	80
No. household members	5.14	2.44	1	14
Years in formal education	7.51	3.36	1	17
Female (%)	72%			
Married (%)	26%			
Millet main porridge consumed (%)	67%			
Children 6 to 59 month (%)	79%			
Porridge consumption				
4 to 7 times per week	60%			
1 to 3 times per week	36%			
1 to 3 times per month	4%			
Cowpea leaf consumption				
4 to 7 times per week	4%			
1 to 3 times per week	50%			
1 to 3 times per month	18%			
Less than once per month/never	28%			
Nutrition awareness¹				
I am eating enough vegetables for good health	3.96	1.03	1	5
I compare labels to select the most nutritious food	3.28	1.15	1	5
I usually look for health information when I buy food products	3.36	0.97	1	5
When at the market I look for food that supports the prevention of diseases	3.76	1.03	1	5
When at the market I look for food that supports a strong immune system	3.92	0.86	1	5
When at the market I look for food that supports good eyesight	3.72	1.02	1	5
N	102			

¹5-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree.

Table 4. Results of the sensory analysis.

Characteristic	CLP_Millet Mean (SD)	Millet Mean (SD)	% CLP_Millet ≥ Millet	CLP_Maize Mean (SD)	Maize Mean (SD)	% CLP_Maize ≥ Maize
Color	3.26 ^a (1.34)	4.26 ^b (1.09)	42	2.62 ^c (1.39)	3.75 ^d (1.33)	45
Aroma	2.93 ^a (1.31)	3.99 ^b (1.13)	41	2.85 ^{ac} (1.40)	3.72 ^{bd} (1.32)	51
Texture in the mouth	3.60 ^a (1.30)	4.37 ^b (0.87)	46	3.25 ^c (1.35)	3.95 ^d (1.39)	40
Taste	3.22 ^a (1.45)	4.27 ^b (1.08)	35	3.20 ^{ac} (1.39)	4.18 ^{bd} (1.09)	50
General appearance	3.57 ^a (1.19)	4.55 ^b (0.67)	46	3.37 ^{ac} (1.27)	4.26 ^d (0.99)	46
WTP (US\$)	0.22 ^a (0.18)	0.26 ^b (0.19)	48	0.22 ^{ac} (0.21)	0.23 ^{abcd} (0.19)	52
N	102	102		102	102	

The letters a,b,c,d reflect significant differences ($p < 0.05$) in a characteristic between the porridges according to Kruskal-Wallis and Duncan-T; % CLP_Millet ≥ Millet = Percentage of participants who rated the porridge combined with CLP at least as high as the plain porridge.

combined porridges that was at least as high as the price for the respective plain porridge (liker) and b) the ones

who were not willing to pay that price (non-liker) (Table 6). In total, 48 participants were likers. The frequency of

Table 5. Results of the structural equation model, coefficients are standardized.

Characteristics	Millet			Maize		
	Coef.	SE ^a	p	Coef.	SE ^a	p
Information	0.183	0.104	0.080*	0.146	0.136	0.281
Nutrition (factor)	0.294	0.086	0.001***	-0.008	0.092	0.932
Sensory perception (factor)	-0.119	0.084	0.155	0.132	0.101	0.192
N = 102						
Characteristics	Millet porridge combined with CLP			Maize porridge combined with CLP		
	Coef.	SE ^a	p	Coef.	SE ^a	p
wtp_millet	0.572	0.066	0.000***			
wtp_maize				0.434	0.246	0.078*
Freq. cowpea leaf cons.	0.121	0.012	0.000***	0.040	0.012	0.001***
Information	0.094	0.057	0.099*	0.153	0.117	0.191
Nutrition (factor)	-0.083	0.059	0.156	0.090	0.117	0.441
Sensory perception (factor)	0.267	0.055	0.000***	0.237	0.023	0.000***

^aStandard errors are robust and clustered at market level; *, ** and * reflects significance at 10, 5 and 1% respectively.

Table 6. Participant characteristics by WTP.

Characteristics	Liker	Non-liker	P
	Mean (SD)	Mean (SD)	
Female	73%	70%	0.950
No. household members	5.52 (2.56)	4.80 (2.29)	0.140
Years in formal education	7.83 (3.89)	7.22 (2.81)	0.650
Children 6 to 59 months (binary)	90%	70%	0.03**
Frequency cowpea leaf consumption	4.58 (2.07)	3.56 (2.18)	0.01***
Frequency porridge consumption	6.94 (1.19)	6.98 (1.28)	0.710
Nutrition awareness (factor)	-0.1 (1)	0.09 (0.1)	0.34
Color CLP_millet	2.92 (1.49)	2.35 (1.26)	0.06*
Aroma CLP_millet	3.08 (1.35)	2.65 (1.42)	0.110
Texture CLP_millet	3.48 (1.27)	2.94 (1.46)	0.06*
Taste CLP_millet	3.56 (1.22)	2.98 (1.41)	0.04**
General appearance CLP_millet	3.69 (1.03)	3.09 (1.40)	0.03**
Color CLP_maize	3.54 (1.24)	3.02 (1.39)	0.05**
Aroma CLP_maize	3.33 (1.24)	2.57 (1.28)	0.00***
Texture CLP_maize	3.62 (1.38)	2.85 (1.43)	0.01***
Taste CLP_maize	3.94 (1.14)	3.30 (1.37)	0.02**
General appearance CLP_maize	3.90 (1.06)	3.28 (1.23)	0.01***
N	48	54	

*, ** and *** Reflects significance at 10, 5 and 1% respectively. Likers are participants who were willing to pay at least as much for porridges combined with CLP as for the plain porridges.

cowpea leaf consumption was significantly higher among this group, and nearly everyone had a child between 6 and 59 months. On average, likers rated all sensory characteristics of both combined porridges higher than non-likers did. This effect was found to be statistically significant for all sensory attributes, except the aroma of the millet combined with CLP.

DISCUSSION

Our study was based on combining traditional porridges with nutrient-rich CLP as a channel to incorporate nutritious vegetables into local diets. Regular consumption of CLP-enhanced porridges will improve dietary diversity as they are rich in micronutrients such as iron, zinc, and

vitamin A. Additionally, processing cowpea leaves into more durable powder can reduce post-harvest losses and bridge off-season gaps. Enhancing traditional porridges with CLP thus appeared to be a promising option; under the condition the product meets consumer demand. First of all, our results confirmed the assumption that porridge is a highly suitable product for enhancing nutrition among the rural population, since porridge is frequently consumed by the survey participants (4 to 7 times per week). Focusing on the core of our research question, our results show that almost half of the participants valued the CLP-enhanced porridges at least as high as the traditional, non-enhanced ones. For this group, the enhanced product can provide an easily accessible and cheap source of important nutrients. However, we also found that combining traditional porridges with CLP lowers sensory appreciation. This leads to the conclusion that the combined porridges will not replace the plain ones but might have a chance as an alternative product on the market. The SEM revealed that sensory perception is an essential factor shaping consumers' WTP for CLP-enhanced porridges. The effect sizes of sensory perception in both combined models were higher than of the remaining three variables.

Sensory perception

The importance of sensory perception was consistent with research on nutritionally enhanced food via biofortification such as quality protein maize. Similar to our findings, De Groote et al. (2014) found that sensory characteristics are among the main drivers of consumers' WTP. Resonating with these findings, another experiment conducted by Wanyama et al. (2019) suggested that ingredients with only minor effects on taste and appearance are seen more positively than ingredients that may change food products more notably. Since consumption of (and thus familiarity with) nutritious and locally available cowpea leaves is low (less than once per week) among most study participants, promoting their utilization constitutes a challenge, but at the same time, it can potentially open a group of potential consumers for the enhanced product. We presume that increasing familiarity with cowpea leaves and African leafy vegetables in general will increase the chance of success for the combined porridges. This presumption is supported by our finding that WTP for the combined porridges increases with higher frequency of cowpea leaf consumption.

Information

With respect to the role of information, we found that giving additional information about the products was

partly helpful in improving their demand. Our results show that the WTP for the millet porridges was higher among participants who received further information on their nutritional value. This suggests that participants appreciate knowing about the food they purchase, and confirms results of several other studies conducted in this field (Chowdhury et al., 2011; De Groote et al., 2014; Oparinde et al., 2016). Interestingly, we could not observe the relationship between information and WTP for the maize porridges. We propose that this is due to consumers being aware of the general fact that millet has a higher nutritional value than maize (Orr et al., 2016) and the given information confirmed their beliefs. The phenomenon of people tending towards information that is in accordance to their beliefs has already been studied in the field of psychology and is often referred to as confirmation bias (Nickerson, 1998). It is our interpretation that giving nutrition information is more persuasive if some form of nutritional perception already exists. In sum, it is interesting that different porridge types are perceived differently, and that distinct ways of promotion might be fruitful for each porridge type. While information campaigns drawing on the benefits of CLP could successfully advertise CLP-enhanced millet porridge, a different approach might be necessary for CLP-enhanced maize porridge which stands to reason if we consider that maize porridge is of low nutritional value. We employed only one mixture ratio of porridge flour and CLP throughout the project. The ratio was based on a pre-study determining the highest amount of CLP that was still considered acceptable. We clearly find a trade-off between nutrition enhancement and the loss of consumer acceptance.

Sensory characteristics

Regarding our control variables we found that younger and less educated participants, who are generally likely to have less cooking knowledge and skills, were especially willing to pay for the plain, non-enhanced porridges, which stresses its suitability to reach vast parts of the population at issue. Plain porridges were, in general, valued even higher among younger and less educated participants, possibly because porridge is quick and easy to prepare and does not require specific cooking skills. The analysis also shows that the plain porridge's sensory perception did not play a significant role in shaping consumers' WTP. We assume that porridge is predominantly consumed for caloric intake and not taste.

Limitations

When assessing our findings, we need to elaborate on

some limitations of the survey conducted. First, it could be promising to add cowpea leaves to other suitable food items, like soups or relishes, where their influence on sensory characteristics could be less dominant. Second, we only studied adults. Since nutrient-poor porridges are often used as a complementary food for children in rural areas (Oladiran and Emmambux, 2020), those children would be an important target group of nutritionally enhanced porridges and should be considered in future studies. Moreover, we analyzed consumers as individuals. Since dietary patterns are significantly shaped by social norms and community practices (Kiguli et al., 2019), it could prove fruitful to add a complementary sociological dimension to this area of research. Third, while the BDM-auction has the benefit of being applicable at the point of purchase, the environment is difficult to control which can influence consumers' responses. Consumers are selected spontaneously and sometimes are in a hurry to finish the study. Although, the experiment was incentive driven to ensure everybody was interested to provide an adequate response and theoretically able to purchase the product, it does not reflect all details of a market purchase. Nevertheless, the method has been applied several times and shown to provide reliable data (De Groote et al., 2014, 2018, 2020). Moreover, the setup of the survey was challenging. Since we conducted the survey in outdoor markets, almost 20% of cases had to be removed from further analysis, as sudden weather changes caused disruption and participants left without finishing the survey. Finally, this resulted in a small sample size, leads to results not being conclusive for minor effects. Thus, we can only show tendencies towards the products and not draw causal relations.

Conclusion

Using sensory analysis and WTP, we assessed the potential of enhancing conventional porridges with CLP as a channel to promote inclusion of locally available, nutritious vegetables into meal plans in East Africa. Descriptive results show that sensory scores are lower among CLP-enhanced porridges, as compared to plain porridges. Still, almost half of the consumers rated them at least equally high in terms of WTP, with the general consumption of fresh cowpea leaves being higher in this group. Thus, CLP-enhanced porridges are unlikely to replace plain ones but could provide an alternative for some consumers. Based on our findings, we make the following recommendations. First, priority in future research should be given to sensory attributes relative to conventional products when enhancing their nutritional value. Second, it is important to find ways to reach consumers who barely, or do not, incorporate fresh vegetables into their dietary habits. Third, education is necessary to sensitize consumers to the importance of

diverse and nutrient-rich diets. We expect that a healthy image of the products, which could be generated through information, could be helpful in a mix of marketing measures to promote the products. Fourth, governments should support the utilization of locally available nutritious vegetables to enhance nutrition and lower post-harvest losses simultaneously. This could include supporting training on techniques of processing ALV, as well as education campaigns that raise awareness about dietary quality and nutritional benefits of ALV.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

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Supplementary Material

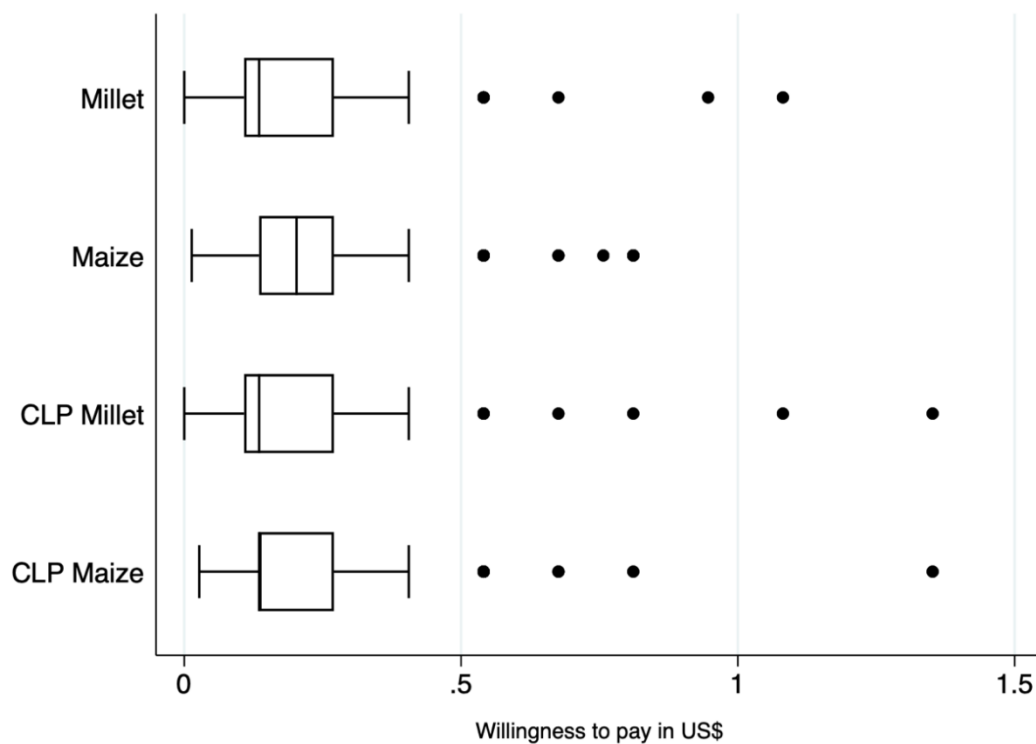
Supplementary Table 1. Participant characteristics, by information.

Characteristics	Information	No information	p
	Mean (SD)	Mean (SD)	
Female (%)	1.75 (0.44)	1.68 (0.47)	0.570
No. household members	4.98 (2.51)	5.30 (2.38)	0.310
Years in formal education	7.04 (3.76)	8.00 (2.84)	0.07*
Children 6 to 59 month (binary)	1.79 (0.41)	1.80 (0.40)	1.000
Frequency cowpea leaf consumption	4.29 (2.08)	3.78 (2.27)	0.390
Frequency porridge consumption	7.02 (1.13)	6.90 (1.34)	0.830
Nutrition awareness (factor)	-0.07 (0.97)	0.07 (1.03)	0.460
Color millet	4.19 (1.21)	4.34 (0.96)	0.670
Aroma millet	3.94 (1.16)	4.04 (1.11)	0.670
Texture millet	4.40 (0.91)	4.34 (0.82)	0.470
Taste millet	4.33 (1.04)	4.22 (1.13)	0.740
General appearance millet	4.52 (0.64)	4.58 (0.70)	0.430
Color maize	3.67 (1.32)	3.84 (1.35)	0.450
Aroma maize	3.62 (1.40)	3.82 (1.24)	0.560
Texture maize	3.87 (1.51)	4.04 (1.26)	0.860
Taste maize	4.13 (1.14)	4.22 (1.06)	0.730
General appearance maize	4.17 (1.10)	4.36 (0.88)	0.510
Color clmaize	2.33 (1.42)	2.92 (1.31)	0.02**
Aroma clmaize	2.73 (1.42)	2.98 (1.38)	0.360
Texture clmaize	3.06 (1.43)	3.34 (1.35)	0.330
Taste clmaize	3.23 (1.28)	3.28 (1.43)	0.770
General appearance clmaize	3.21 (1.27)	3.54 (1.27)	0.190
Color clmill	3.02 (1.36)	3.52 (1.28)	0.06*
Aroma clmill	2.87 (1.40)	3.00 (1.23)	0.580
Texture clmill	3.15 (1.56)	3.28 (1.34)	0.730
Taste clmill	3.56 (1.42)	3.64 (1.17)	1.000
General appearance clmill	3.58 (1.23)	3.56 (1.16)	0.900

Supplementary Table 2. Structural Equation Model including control variables.

Parameter	Millet			Maize		
	Coef.	SE ^a	p	Coef.	SE ^a	p
Female	-0.107	0.092	0.246	-0.125	0.057	0.029**
Age (years)	-0.319	0.126	0.011**	-0.372	0.142	0.009***
Education (years of schooling)	-0.248	0.007	0.000***	-0.150	0.021	0.000***
Information	0.186	0.079	0.019**	0.166	0.118	0.158
Nutrition (factor)	0.283	0.070	0.000***	-0.022	0.114	0.848
Sensory perception (factor)	-0.022	0.096	0.814	0.109	0.118	0.358
N = 102						
Parameter	Millet porridge combined with CLP			Maize porridge combined with CLP		
	Coef.	SE ^a	p	Coef.	SE ^a	p
wtp_millet	0.578	0.068	0.000***			
wtp_maize				0.397	0.282	0.158
Female	0.009	0.068	0.892	-0.012	0.062	0.851
Age (years)	-0.016	0.041	0.702	-0.082	0.094	0.383
Education (years of schooling)	0.041	0.090	0.646	-0.077	0.078	0.323
Freq. cowpea leaf cons.	0.120	0.022	0.000***	0.026	0.027	0.350
Information	0.099	0.052	0.056*	0.159	0.115	0.168
Nutrition (factor)	-0.103	0.093	0.271	0.104	0.118	0.380
Sensory perception (factor)	0.269	0.057	0.000***	0.239	0.024	0.000***

^aStandard errors are robust and clustered at market level. *reflects significance at 10%, **reflects significance at 5%, ***reflects significance at 1%.

**Supplementary Figure 1.** Willingness to pay distribution.