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Consumers' acceptability of extruded maize-sorghum composite flours fortified with grain amaranth, baobab and orange fleshed sweet potatoes

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Porridge is a popular cereal flour-based food product for children in Sub-Saharan Africa. Compositing of cereal flours to improve their nutritional composition is done. However, the enrichment of such flours with naturally nutrient-rich plant products is poorly developed. A study was conducted to evaluate the acceptability and sensory attributes of newly formulated extruded composite flours containing maize, sorghum, grain amaranth, baobab and orange-fleshed sweet potatoes. Seven extruded formulations optimized for nutritional composition were developed. Twelve trained panellists evaluated the sensory attributes and overall acceptability of the composite flours determined on a 9-point hedonic scale. Formulation of the composite flours significantly ($p<0.05$) affected scores of colour, flavour and overall acceptability with the mean score ranging between 5.7 and 7.4. There was no significant difference ($p>0.05$) on overall acceptability between extruded and non-extruded composite flours but extruded flours had significantly higher scores on texture ($p<0.05$). The comparison of the newly formulated composite flours with the conventional flours showed no significant difference ($p>0.05$) in the overall acceptability; therefore, they can be potentially adopted. All the sensory attributes contributed to the overall acceptability of the formulations, with mouthfeel and flavour having higher relationship with overall acceptability. It is concluded that these attributes are desirable characteristics of any new naturally fortified cereal formulation.

Key words: Extruded, composite flour, formulation, sensory evaluation.

INTRODUCTION

Micronutrient, especially iron, zinc, vitamin A and iodine deficiency is prevalent in developing countries despite the employment of different strategies to help reduce the challenge (Faber et al., 2014; Osendarp et al., 2018). Food fortification methods employed to address the deficiencies include food to food fortification, industrial

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fortification with inorganic compounds, oral supplements and biofortification through plant breeding and genetic engineering (Mannar and Wesley, 2016). Food insecurity in developing countries and the high cost of commercially fortified food hinder the reduction of micronutrient deficiencies (Akinsola et al., 2018); therefore, there is a need to develop cost-effective and sustainable strategies for improving the nutritional status of food.

Food to food fortification is one of the cheapest interventions used to alleviate micronutrient malnutrition in developing countries (Chadare et al., 2019; De Groote et al., 2020; Morilla-Herrera et al., 2016). More attention is given to composite flours for making porridge because it is the most consumed food by low-income families in most African countries (Ajifolokun et al., 2019; Udomkun et al., 2019). Porridge is commonly prepared from cereals, which are low in most nutrients hence the rise in the formulation of composite flours from different locally available foods (Elina et al., 2016). Formulated products have different sensory characteristics which can be caused by the different ingredients and the changes they undergo during processing (Adedola et al., 2019; Gitau et al., 2019). Thus, there is need to assess the acceptability of the new formulations before releasing them to the market.

Flour blending has been adopted as one of the techniques for improving the micronutrient composition of cereal flours. In addition to augmentation of the nutrient composition, flour blending improves its rheological, physical and sensory properties (Adedola et al., 2019). However, some balance needs to be achieved in compositing: for example, composite flours containing sorghum are acceptable to a point but as the amount of sorghum increases, liking of the colour decreases because of dark pericarps found in red sorghum varieties that may cause undesirable dark colour in food products (De Groote et al., 2020; Omwamba and Mahungu, 2014). Baobab pulp is rich in ascorbic acid; it improves the flavour of food products and their acceptability (Mounjouenpou et al., 2018; Netshishivhe et al., 2019). In as much as amaranth grain flour flavour is not preferred on its own, Joshi et al. (2019) found that composite flours containing up to 25% of grain amaranth were acceptable. Orange fleshed sweet potatoes affect the colour and flavour of food which makes it desirable in composite flour formulations (Pereira et al., 2019).

Extrusion is a food processing method that has been widely used in the production of pasta, breakfast cereals and snacks (Leonard et al., 2020). It is currently being used in the production of nutritious instant composite flours with better sensory attributes (Otondi et al., 2020). Extrusion temperature and feed moisture are known to affect the colour and texture of extrudates (Gbenyi et al., 2016).

Composite flours containing maize, sorghum, amaranth grain, OFSP and baobab have been formulated, but the effect of formulation and extrusion on their sensory attributes has not been studied. Therefore, the current study aimed at evaluating the sensory attributes and consumer acceptability of the newly formulated extruded composite flours.

MATERIALS AND METHODS

Sample acquisition

The raw materials were sourced from different parts of Kenya. Maize was obtained from Eldoret Market located in the Rift valley. Pale-red sorghum (E97) and pale cream amaranth grain were obtained from Busia and Bungoma, Western Kenya. Baobab powder was obtained from Mombasa and the sweet potato puree was obtained from Organi® Ltd in Homabay. The dry foodstuffs were stored at 25°C and the potato puree was stored in a deep freezer at -20°C.

Sample preparation

The grains were cleaned and dried in a forced-air draft oven at 60°C for 24 h to a moisture content of about 12%. Frozen orange-fleshed sweet potato (OFSP) puree was thawed in hot water, and oven-dried at 60°C for 6 h. The dry grains and OFSP were separately milled in an 800 µm sieve-hammer mill and whole-meal flours were obtained.

Formulation of the composite flours

The composite flour formulations were based on the findings of the nutritional profile of each of the ingredients (unpublished work) to meet the Recommended Dietary Allowance (RDA) of children below the age of five years based on World Health Organization (WHO) recommendations. Nutrisurvey linear programming software embedded with WHO RDA for children was used in the formulation of the flours (NutriSurvey, 2007). The formulations targeted 25% RDA of beta-carotene, iron and zinc contents and 15 % RDA of protein. Seven formulations were developed (Table 1).

The flours were thoroughly mixed and half of each mixture was stored separately as the control; whereas the other half was processed through extrusion. The moisture content of the other half was raised to 35% by adding water and mixing thoroughly and extruded at 160°C in a single screw extruder (TechnoChem, Indiana, USA) with a screw rotation of 800 rpm. The extruded products were dried at 50°C for 4 h, milled and vacuum-packed in polythene bags and transported in boxes to Nairobi for sensory evaluation. The best flour was selected for comparison with commercial flours.

Acquisition of commercial composite flours for comparison

Commercial composite flours containing maize and sorghum for comparison were obtained from different supermarkets in Nairobi Kenya as described in Table 2.

Porridge preparation

Thin porridge was prepared by modifying the method described by Onyango et al. (2020). Briefly, 40 g of the composite flour was added to 200 mL of cold water and thoroughly mixed with a wooden ladle. It was transferred to a stainless-steel pot containing 640 mL of boiling water and stirred continuously for 5 min. It was boiled for

Table 1. Composite flour formulations.

Formulation	Ingredient proportion (%)					Description
	Maize	Sorghum	Amaranth	OFSP	Baobab	
F1	30	35	20	10	5	Varying cereals and fortificants
F2	42.5	22.5	5	15	15	More maize than sorghum with constant fortificants
F3	22.5	42.5	5	15	15	More sorghum than maize with constant fortificants
F4	32.5	32.5	5	15	15	Equal maize and sorghum, constant fortificants
F5	65	0	5	15	15	Maize plus constant fortificants
F6	0	65	5	15	15	Sorghum plus constant fortificants
F7	20	45	5	15	15	A variant of formulation C

Table 2. Commercial composites for comparison.

Market composites	Composition
S1	Formulated flour containing sorghum, maize, baobab, grain amaranth and orange-fleshed sweet potato (the best formulation)
S2	Millet, sorghum, lemon and souring agent blended flour
S3	Finger millet, maize, wheat, amaranth, soya and sorghum cereal flour blend
S4	Finger millet, maize, sorghum and souring agent cereal flour blend
S5	Sorghum, maize, vitamins and minerals flour blend
S6	Soya beans, groundnuts, beans, finger millet, cassava, maize and silverfish flour blend
S7	Maize, millet, sorghum, soya and groundnuts flour blend
S8	Maize, sorghum and soy flour blend

10 min and transferred to vacuum flasks.

Sensory evaluation

Sensory evaluation was carried out at Kenya Bureau of standards laboratories in Nairobi by modifying the method described by Onyango et al. (2020). Twelve sensory evaluation panellists were recruited, trained on sensory attributes for 6 h using sample porridges with different attributes. The first 3 h involved attribute generation while the rest of the time was used to identify references that match with the attributes (Table 3) and how to rate them on a 100 mm unstructured scale.

During the actual evaluation, coded clear plastic cups with 50 g of porridge were served to the panellists. A cup of drinking water was also provided for the panellists to rinse their mouths between samples. All the attributes of each sample were fully evaluated using the provided questionnaire before the next sample was served and the results were recorded in duplicate.

Data analysis

The data were analysed using the *R* Project for *Statistical* Computing, R-3.6.3 (R Core Team, 2019). The normality of the data was first tested using Wilk's Shapiro test with the data that were not normal transformed to z-distribution before inferential analysis. Descriptive statistics, including mean and standard deviation, were determined for the formulations and treatments. Analysis of variance (ANOVA) was used to establish significant differences in the mean sensory scores of attributes with different means separated using Tukey's HSD test at $p<0.05$. The product with the highest sensory scores was evaluated against commercial conventional blended flours retailed in the market and their means compared using ANOVA. Data exploration was done using clustering and principal component analysis.

RESULTS

Sensory attributes of blended cereal flours

Formulation, extrusion and their interaction affected sensory attributes of the formulated composite flours significantly ($p<0.05$). The scores of the new formulations in terms of the colour, texture, mouthfeel, flavour and overall acceptability were all acceptable (Table 4). Based on colour, F7 was the most acceptable (7.4±1.38) while F2 was the least acceptable (6.13±1.70). F7 was also the most acceptable for texture (6.88±1.54) as compared to F1 which scored the least (6.05±1.83). Based on the mouthfeel, F3 was the most acceptable (7.40±1.34) while F2 had the lowest score (6.25±2.26). F7 was the most acceptable based on flavour and overall acceptability (7.55±1.06 and 7.43±1.24). With a lower proportion of sorghum, the liking of the colour of the blended flour significantly ($p<0.05$) increased. Formulations with the highest proportion of amaranth grain powder had the least scores for flavour and overall acceptability ($p<0.01$).

Evaluation of extrusion as the main effect shows that

Table 3. Descriptive sensory lexicon developed by the sensory evaluation panel to evaluate the quality of porridge.

Attribute	Description	Reference and rating scale
Appearance		
Colour	Discernment of colour ranging from white to dark brown	Corn starch (10% w/v) stirred in hot water = 0 (white) [a]Dairy land dark compound chocolate = 10 (dark brown)
Brown and dark specks	Quantity of brown and dark specks in porridge when smeared on a white surface	Corn starch (10% w/v) stirred in hot water = 0 (no dark specks) Whole milled sorghum flour (30% w/v) stirred in hot water = 10 (many dark specks)
Flavour		
Maize flavour	Flavour characteristic of maize flour in hot water	Whole-milled maize flour (30% w/v) stirred in hot water = 10 (very intense)
Sorghum flavour	Flavour characteristic of sorghum flour in hot water	Whole-milled sorghum flour (30% w/v) stirred in hot water = 10 (very intense)
Grain amaranth flavour	Flavour characteristic of grain amaranth flour in hot water	Whole-milled grain amaranth flour (30% w/v) stirred in hot water = 10 (very intense)
Baobab powder flavour	Flavour characteristic of baobab fruit pulp flour in hot water	Whole-milled baobab pulp flour (30% w/v) stirred in hot water = 10 (very intense)
OFSP flavour	Flavour characteristic of OFSP flour in hot water	Whole-milled OFSP flour (30% w/v) stirred in hot water = 10 (very intense)
Taste		
Sour taste	The taste associated with lemon juice	[b]Quencher mineral water = 0 (not sour) Whole-milled finger millet porridge (10% w/v) containing 1% w/v citric acid solution = 10
Texture		
Viscosity	Resistance to flow when the porridge is poured in another cup	[c]KCC gold crown milk (fat content 3.5%) = 0 (thin) [d]Daima thick yoghurt= 10 (thick)
Coarseness	The extent to which particles are perceived in the mouth in the process of chewing	Honey = 0 (not perceived) Fresh blended, unsieved watermelon juice = 10 (intensely perceived)
Mouth feel		
	Physical sensation in the mouth	[e] Krackles crisps= 0 (crispy) [d] Daima thick yoghurt= 10 (smooth)
After swallow		
Sour aftertaste	Perception of lingering sourness in the mouth after chewing and swallowing	10= Strong after taste
Residual particles	Perception of particles in the mouth after swallowing porridge	Fresh blended, unsieved watermelon juice = 10 (many residual particles)

[a]Topserve limited Kenya; [b]Excel chemicals limited, Nairobi; [c]New Kenya co-operative creameries, Nairobi Kenya; [d]Sameer Agriculture, Kenya and [e]Propack Kenya Limited, Nairobi.

extruded flour had significantly ($p<0.05$) higher scores for texture than the non-extruded flours (control) as shown in Figure 1. The extruded composite flours had slightly higher scores on colour (6.8), texture (6.9) and mouthfeel (6.8) compared to the non-extruded flours (control) which were better in flavour and overall acceptability with the scores ranging between 6.5 and 7.4.

Interaction of extrusion and the formulation as treatments resulted in significant ($p<0.05$) differences in the sensory scores of texture and flavour (Table 5). Control (non-extruded) formulations with higher amaranth content and those that were extruded with higher maize content had significantly ($p<0.05$) least scores for texture (5.35±1.42 and 5.65±1.69) respectively. For flavour, the extruded

Table 4. Main effect of formulation on the sensory attributes of non-extruded composite flours.

Formulation	Colour	Texture	Mouthfeel	Flavour	Overall acceptability
F1	7.08±1.61[ab]	6.05±1.83[a]	6.30±2.05[a]	5.90±2.01[a]	5.65±1.63[b]
F2	6.13±2.05[a]	6.83±1.58[a]	6.25±2.26[a]	6.78±2.14[ab]	6.98±1.73[a]
F3	6.85±1.70[ab]	7.08±1.31[a]	7.40±1.34[a]	6.95±1.48[ab]	7.23±1.19[a]
F4	6.68±1.51[ab]	6.83±1.55[a]	6.90±1.53[a]	6.95±1.13[ab]	6.75±1.43[a]
F5	6.18±2.32[a]	6.05±1.85[a]	6.58±1.69[a]	6.65±1.90[ab]	7.03±1.46[a]
F6	6.73±1.87[ab]	6.78±1.85[a]	6.78±1.87[a]	6.70±1.76[ab]	6.68±1.56[a]
F7	7.43±1.38[b]	6.88±1.54[a]	6.88±1.80[a]	7.55±1.06[b]	7.43±1.24[a]
%CV	27.3	25.3	27.3	25.1	22.8
p-value	0.013	0.116	0.083	0.002	<0.001

The values are mean ± SD. Values with the same superscript in a column are not statistically different at p>0.05. The samples (F1-F7) are as described in Table 1.

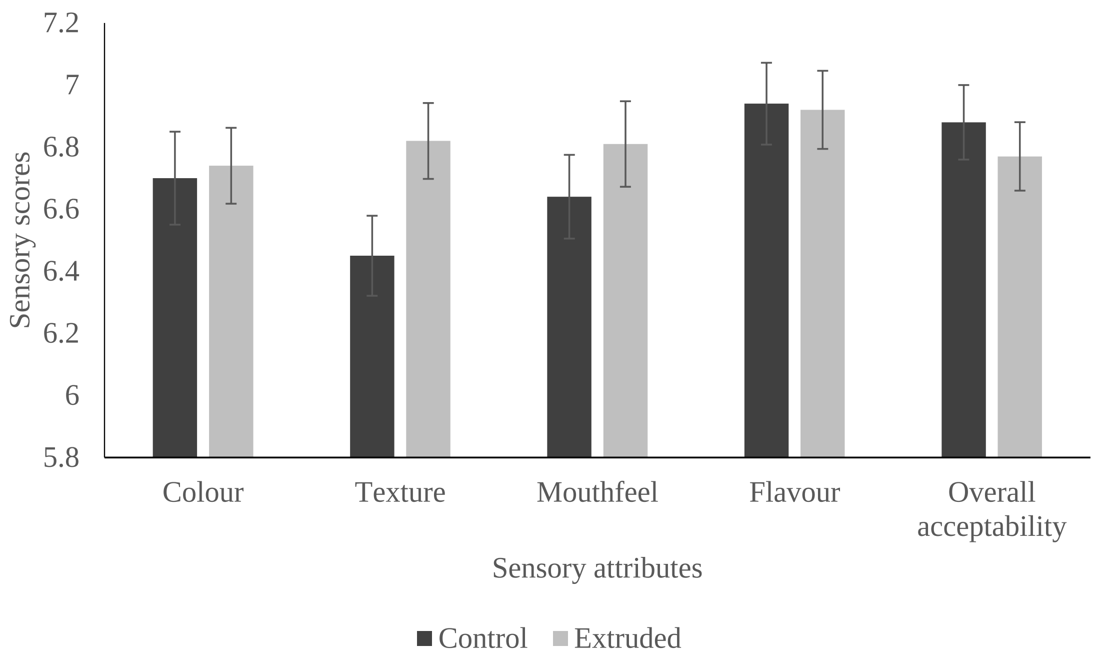

Figure 1. Main effects of extrusion on the sensory scores of blended cereal flours.

formulation with a higher content of amaranth had significantly ($p<0.05$) the least sensory scores. The principal component analysis showed that all the four attributes contributed to the overall acceptability of the formulations with mouthfeel and flavour having a higher relationship with the overall acceptability as shown in Figure 2.

Comparative sensory quality of blended flours to the conventional flours

The formulated flour (S1) had significantly ($p<0.001$) lower scores for colour compared to the commercial conventional flours (Table 6). The overall acceptability of the formulated cereal flours had no significant difference ($p>0.05$) with the most acceptable cereal flour blends in the market.

Clustering of sensory qualities of the blended flours

The sensory attributes of the flour blends are maximally explained by two clusters explaining 87.3% in the data variability. Cluster 1 had higher scores in all the four sensory attributes evaluated (Figure 3); colour, mouthfeel, flavour and overall acceptability. Except for the flour blends that had limited ingredients that majorly constituted

Table 5. Effect of the interaction between extrusion and formulation on sensory attributes of blended cereal flours.

Sample	Treatment	Colour	Texture	Mouth feel	Flavour	Overall acceptability
F1	Extruded	6.55±1.85[a]	6.75±1.94[a]	6.40±2.62[a]	5.05±1.79[b]	5.25±1.83[a]
	Control	7.60±1.14[a]	5.35±1.42[b]	6.20±1.32[a]	6.75±1.89[ab]	6.05±1.32[a]
F2	Extruded	6.26±1.48[a]	6.50±1.82[a]	6.20±2.04[a]	6.70±2.00[ab]	6.75±1.59[a]
	Control	6.00±2.53[a]	7.15±1.27[a]	6.30±2.52[a]	6.85±2.32[ab]	7.20±1.88[a]
F3	Extruded	6.80±1.67[a]	7.30±1.22[a]	7.60±1.05[a]	7.35±1.04[ab]	7.55±0.94[a]
	Control	6.90±1.77[a]	6.85±1.39[a]	7.20±1.58[a]	6.55±1.76[ab]	6.90±1.33[a]
F4	Extruded	7.05±1.36[a]	7.40±1.14[a]	7.10±1.45[a]	6.95±1.10[ab]	6.85±0.88[a]
	Control	6.30±1.59[a]	6.25±1.71[a]	6.70±1.63[a]	6.95±1.19[ab]	6.65±1.84[a]
F5	Extruded	6.15±1.69[a]	5.65±1.69[b]	6.25±1.68[a]	6.30±1.49[ab]	6.90±1.12[a]
	Control	6.20±2.86[a]	6.45±1.96[a]	6.90±1.68[a]	7.00±2.22[ab]	7.15±1.76[a]
F6	Extruded	6.80±1.94[a]	7.00±1.49[a]	6.70±1.92[a]	6.35±1.87[ab]	6.55±1.61[a]
	Control	6.65±1.84[a]	6.55±2.16[a]	6.85±1.87[a]	7.05±1.61[ab]	6.80±1.54[a]
F7	Extruded	7.60±1.14[a]	7.15±1.31[a]	7.40±1.50[a]	7.65±0.99[a]	7.45±1.10[a]
	Control	7.25±1.59[a]	6.60±1.73[a]	6.35±1.95[a]	7.45±1.15[ab]	7.40±1.39[a]
%CV		27.3	25.3	27.3	25.1	22.8
p-value		0.428	0.016	0.519	0.030	0.411

The values are mean ± SD. Values with the same superscript in a column are not statistically different at p>0.05. The samples (F1-F7) are as described in Table 1.

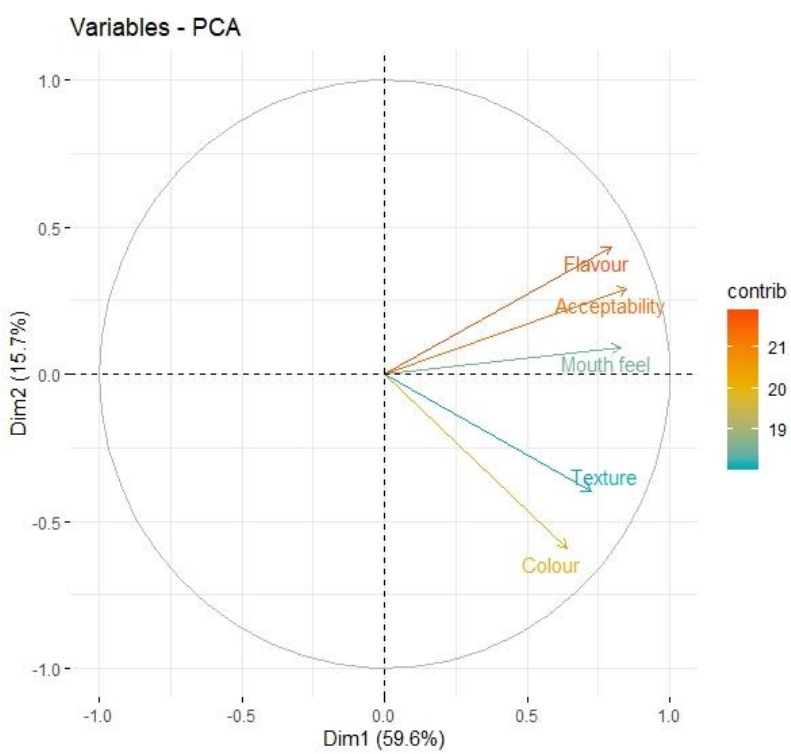

Figure 2. Principal components explaining data variability of the sensory scores for the formulated flour blends.

Table 6. Comparison of the formulated flour against conventional flour retailed in the market.

Sample	Colour	Mouthfeel	Flavour	Acceptability
S1	5.58±1.82[c]	5.63±1.74[ab]	6.21±1.89[a]	6.33±1.66[ab]
S2	8.04±0.81[a]	6.42±2.02[a]	6.21±1.86[a]	7.25±1.26[a]
S3	7.46±1.25[ab]	6.75±1.59[a]	6.63±1.53[a]	7.29±1.55[a]
S4	5.71±1.12[c]	6.46±1.67[a]	6.75±1.65[a]	6.79±1.50[a]
S5	3.25±1.75[d]	4.42±1.86[b]	4.33±2.06[b]	4.46±2.13[c]
S6	7.96±1.04[s]	6.67±1.24[a]	6.63±1.41[a]	7.13±1.26[a]
S7	6.04±2.37[bc]	5.63±2.04[ab]	6.04±1.90[a]	6.46±1.98[a]
S8	3.17±2.10[d]	4.79±2.26[b]	5.29±2.65[ab]	4.88±2.27[bc]
%CV	40.7	33.8	33.6	31.4
p-value	p<0.001	p<0.001	p<0.001	p<0.001

The values are mean ± sd. Values with the same superscript in a column are not statistically different at p>0.05. The samples (S1-S8) are as described in Table 2.

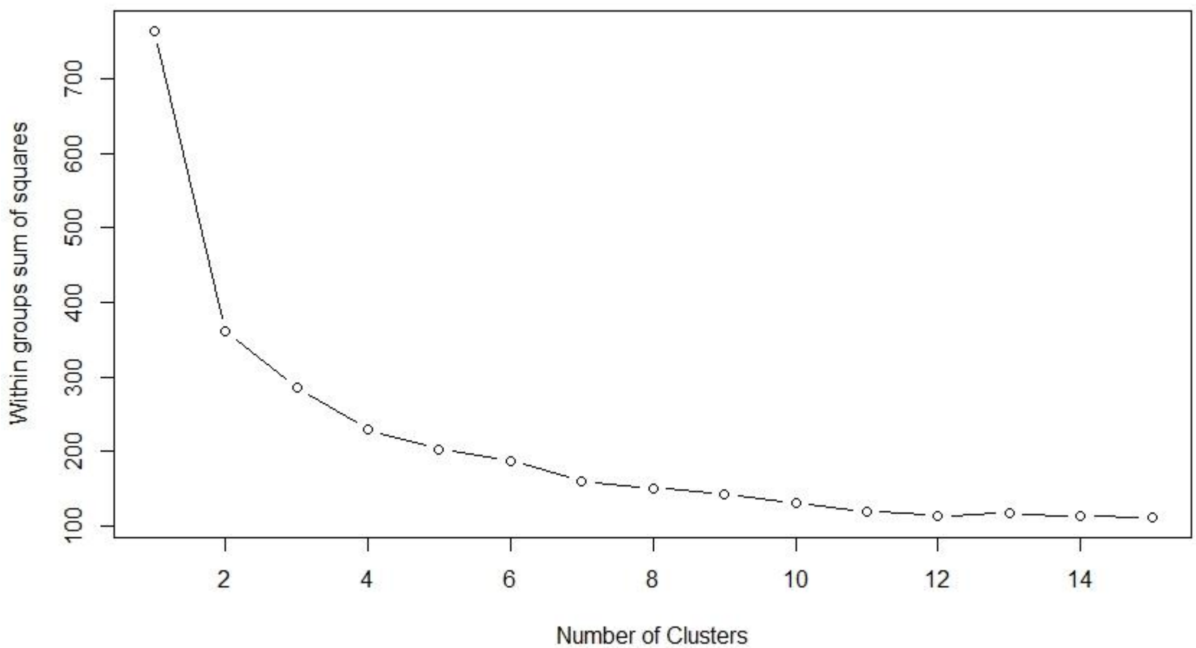

Figure 3. WSSplot for clustering of the sensory attributes of cereal flour blend.

cereals as the ingredients, all other flour blends were in cluster 1 (Figure 4). All the three attributes contributed towards determining the overall acceptability of the cereal flour blends (Figure 5). However, mouthfeel and flavour had a closer relationship with the overall acceptability (Figure 6).

DISCUSSION

The formulated composite flours varied in colour, flavour and overall acceptability. Flours with lower sorghum contents had better scores in terms of colour. This finding is similar to that reported by Tegeye et al. (2019) who reported that increasing the proportion of fortificants tends to improve the liking of colour among the consumers. An increase in amaranth content in the formulations resulted in a decrease in flavour scores which agrees with other studies. Studies by Joshi et al. (2019) found that composite flours containing 25% amaranth were more acceptable. Akande et al. (2017), on the other hand, found that adding up to 35% amaranth grain in porridge composites left an aftertaste that was not liked by consumers.

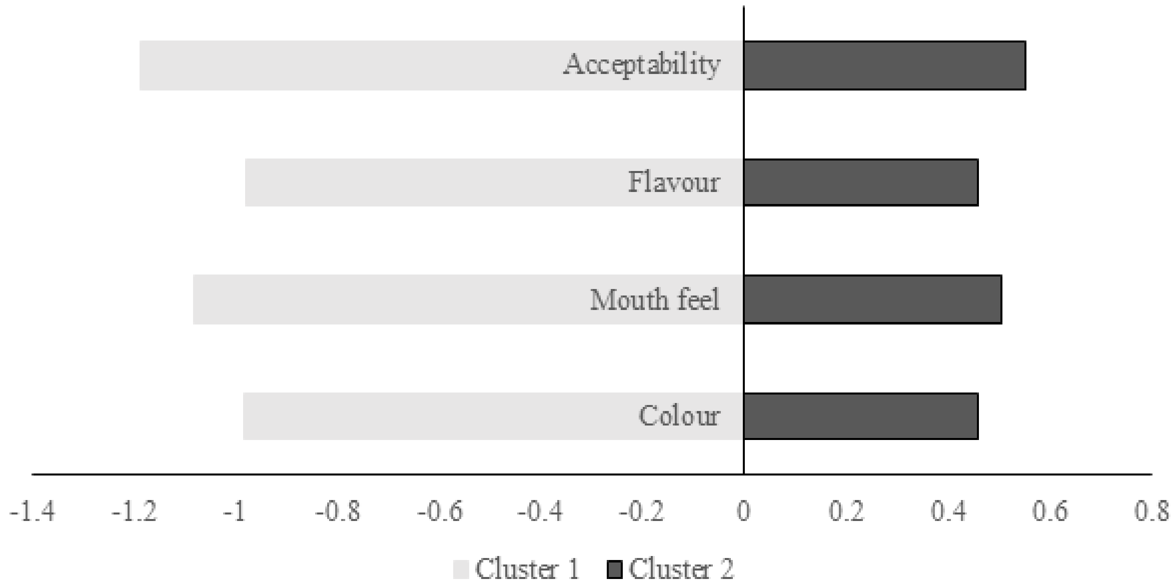

Figure 4. Clustering of the sensory attributes of blended flours (both formulated and conventional ones). The values were transformed into z-distribution where the mean is 0 and the standard deviation is 1.

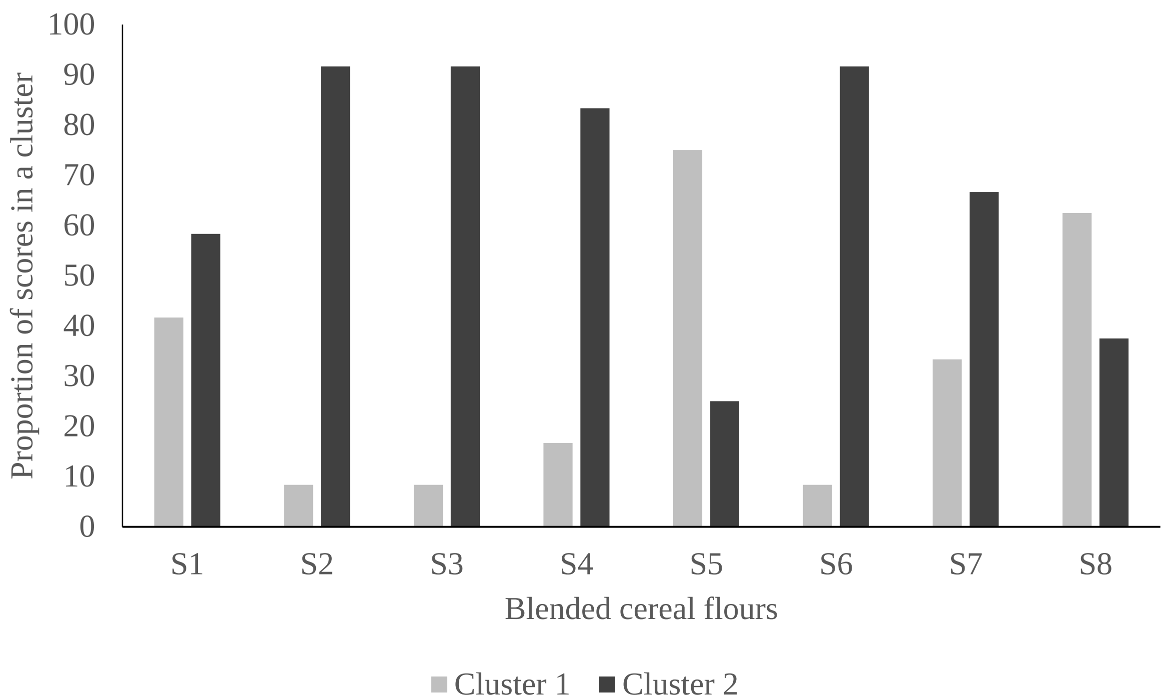

Figure 5. Proportion of the sensory scores of blended flours loaded into the clusters.

Extrusion affected the sensory scores in terms of colour and texture of the composites. This may be due to extrusion temperature and feed moisture which is known to affect the colour of the final product through mallards reaction, non-enzymatic browning and pigment destruction reactions (Adams et al., 2019; Gbenyi et al., 2016). Extrusion imparts a soft texture to extruded products hence the preference in texture (Patil et al.,

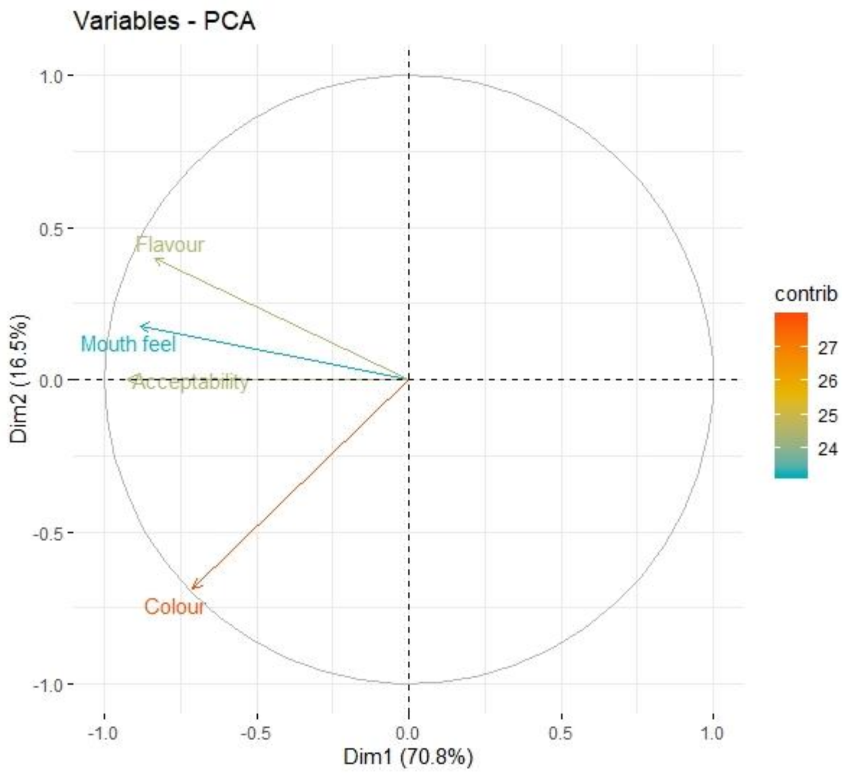

Figure 6. Principal Component Analysis plot of the sensory attributes of blended flours.

2016). This may also be attributed to texturisation that occurs during extrusion (Sun et al., 2019). Non-extruded flours had course texture because the flours were wholemeal and only milled once while the extruded ones were milled two times, before and after extrusion (Heiniö et al., 2016). Extrusion reduced the coarse properties of sorghum flour and improved overall acceptability and flavour of sorghum wheat composites (Jafari et al., 2018). This finding implies that consumers will tend to have a higher liking for the extruded flour with a softer texture than the non-extruded ones.

The study established that the attributes of colour, flavour and mouthfeel are essential sensory qualities that contribute towards acceptability of food products. These findings are in agreement with Eze et al. (2020) and Ramírez-Jiménez et al. (2018) who reported that aroma, taste, mouthfeel and colour were the major determinants of acceptability. However, the mouthfeel and flavour were found to be greater contributors in improving the acceptability of the products compared to colour. Therefore in developing product qualities, much more attention should be put in improving mouthfeel and sensory qualities (Elina et al., 2016).

There was no significant difference in the overall acceptability of the new formulation compared to the market blends. This means that all the flours were equally accepted which agrees with the study conducted by Elina et al. (2016). However, it contradicts earlier studies that indicated that extruded products were disliked by consumers due to flavour changes that develop during extrusion (Muoki et al., 2012).

The newly formulated flours scored low on colour which can be attributed to the extrusion process which increases the intensity of the colour. Eze et al. (2020), in their study, found that extruded flours had more intense colour and better mouthfeel and liking compared to conventional flours. Thus, there is need to improve the colour attribute for enhanced acceptability. This also explains the low determinant level in overall acceptability of the cereal flour blends attributable to colour. Mouthfeel was highest for flours containing finger millet, maize, wheat, amaranth, soya and sorghum (6.75). This could be attributed to the use of roasted soya that is known to improve the taste of food (Gitau et al., 2019; Maria and Anuoluwapo, 2018).

Conclusion

Formulation affected the colour, flavour and the overall acceptability of maize, sorghum, amaranth grain, baobab and orange-fleshed sweet potato composite flours with the formulations containing higher sorghum amounts being the most acceptable while extrusion affected the texture scores. The composite flours were all liked thus indicating the potential of the new formulations to be adopted. Colour, flavour, texture and mouthfeel contributed to overall acceptability of the composite flours with the major contributors being mouthfeel and flavour. Flavour and mouthfeel are therefore desirable characteristics of any new formulations of cereal flour blends in the food industry.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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