Rapid sensory profiling and hedonic rating of whole grain sorghum-cowpea composite biscuits by low income consumers

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Abstract

BACKGROUND

The challenges of malnutrition and urbanization in Africa demand development of acceptable, affordable, nutritious complementary-type foods. Biscuits (cookies), a popular snack, from whole grain staples is an option. The objective was to relate check-all-that-applies (CATA) sensory profiles of sorghum-cowpea composite biscuits compared to economic commercial refined wheat biscuits with hedonic ratings by low income consumers. In addition, the nutritional composition and protein quality, L*a*b* colour and texture of the biscuits were determined.

RESULTS

The CATA method is suitable to rapidly determine which attributes consumers perceive in food products and relate these to acceptability. Consumers preferred the lighter, more yellow wheat biscuits with ginger, vanilla, sweet and cinnamon flavours more than the stronger flavours (sorghum, beany and nutty) and harder but brittle, grittier, dry and rough textured sorghum or sorghum-cowpea biscuits. However, a substantial proportion of consumers also liked the latter biscuits. The composite biscuits had higher dietary fibre content and similar protein quality to the standards.

CONCLUSION

Whole grain sorghum-cowpea biscuits could serve as acceptable value-added nutritious complementary snacks for consumers in sub-Saharan Africa. The biscuits are simple to produce for creation of viable small enterprises.

INTRODUCTION

Sub-Saharan Africa is the most food insecure region of the world, where some 24% of people are undernourished.[1] Poverty is a major contributing factor. The malnutrition takes two main forms: macronutrient (primarily protein-energy malnutrition, PEM) and micronutrient malnutrition, the so-called hidden hunger (primarily inadequate vitamin A, iron and zinc intake).[2] Traditionally, many rural African communities prepared protein- and micronutrient-rich meals from indigenous cereals and legumes[3], such as sorghum and cowpeas. Today, sorghum and cowpeas are still major staple crops in Africa due their adaptation to harsh, dry climatic conditions. Sorghum production is some 29 million tons and cowpea five million tons, making them the joint second most important cereal and legume cultivated in Africa (FAOSTAT (http://www.fao.org/faostat/en/#data/QC)).

Africa is now rapidly urbanizing and it is estimated that by 2030 more than half of the continent's population will live in cities (United Nations (https://esa.un.org/unpd/wup/)). The dual challenge of malnutrition and urbanization in Africa demand development of nutritious complementary-type foods that will be consumed by modern communities. Biscuits (cookies) are an excellent complementary food vehicle because they are a popular snack, energy-rich, have a long shelf-life and are consumed without need for further preparation. Biscuits made from refined sorghum flour composited with defatted soy flour can contribute substantially to the protein requirements of young school-age children and that such biscuits are sensorially acceptable to urban-dwelling children.[4]

Lately, the consumption of whole grain foods is being strongly promoted because the inclusion of the bran layers of the grain considerably enhances their contents of micronutrients (B and E vitamins and essential minerals), phytochemicals such as phenolic compounds, carotenoids and sterols, and dietary fibre.[5] Additionally, a practical advantage of whole grain foods is that the milling technology to produce whole grain flour is much simpler than for refined flour. Posho (hammer) mills which are common across sub-Saharan Africa,[6] are suitable. Whole grain products are therefore potentially less expensive and more suitable for small enterprises. Biscuits made from whole grain sorghum or pearl millet flour composited with defatted soy flour could make a substantial contribution to the dietary fibre and mineral requirements of young school-age children.[7] However, the study also indicated that determination of the consumer acceptability of such whole-grain biscuits is critical.

Check-all-that-applies (CATA) is a rapid sensory profiling methodology developed to obtain sensory information from consumers to determine which sensory attributes they perceive in a food product.[8,9] CATA consists of a list of attributes or terms from which the respondents should select all attributes they consider relevant to describe a specific food product. The terms are generated either based on previous research or by trained panellists and/or by using a focus group discussion. An advantage of the CATA method is that it is a spontaneous method, minimizing time of evaluation and cognitive effort, and also it is regarded as an appropriate method to use with naïve consumers.[9,10] The CATA profiling method is a rapid, inexpensive way to provide information on the reasons why consumers like or dislike products, but has not been applied extensively with low income consumers. The application of CATA with low income consumers has been reported only once previously and then to determine emotions related to food choice.[11]

The objective of this study was to relate the sensory profiles, using the rapid CATA method, of whole grain sorghum and cowpea composite biscuits compared to existing low cost commercial refined wheat snack biscuits, with liking ratings. Evaluation was done by a group of resource-constrained, low income urban consumers in South Africa. Acceptance of the sensory properties of such nutritionally and/or economically beneficial food products is key to consumers. In addition, the overall nutritional composition and protein quality, instrumental L*a*b* colour and texture properties of the biscuits were also determined to provide further understanding of the consumers' responses.

MATERIALS AND METHODS

Formulation and preparation of biscuits

Two sorghum cultivars, Orbit a white tan-plant, non-tannin (white sorghum) and MR Buster a red, non-tannin (red sorghum) and one cowpea variety (Bechuana white) were used. The grains were milled using a laboratory hammer mill (Falling Number 3100, Huddinge, Sweden) fitted with a 500 µm screen to give whole grain flours. These were stored in air-tight containers at <10 °C prior to biscuit preparation and other analyses.

Table 1 shows the formulations for the four different biscuit treatments. Composite flours were prepared by mixing whole grain sorghum flour and whole grain cowpea flour at a ratio of 60:40. When cowpea flour was added less water was needed to form a firm biscuit dough. Two types of commercial economic wheat snack biscuits, Shortbread and Original (Casa Mia Biscuits, Nancefield, South Africa) were used as standards.

Table 1 Formulations of four types of biscuits: red and white whole grain sorghum and red and white whole grain sorghum[1]-cowpea[2] composite biscuits

Ingredients	Sorghum[1]	Sorghum[1]: Cowpea[2]
Sorghum: Cowpea ratio	**100:0**	**60:40**
Whole grain sorghum flour (g)	450 (100)[3]	270 (60)
Whole grain cowpea flour (g)	0	180 (40)
Sugar (g)	112 (24.9)	112 (24.9)
Sunflower oil (g)	132 (29.3)	132 (29.3)
Baking powder (g)	3 (0.7)	3 (0.7)
Vanilla essence (g)	27 (0.6)	27 (0.6)
Water (g)	157.5 (35.0)	103.5 (23.0)
Total dough weight (g)	881.5	827.5

[1] Sorghum cultivars, Orbit a white tan-plant, non-tannin (white sorghum) and MR Buster a red, non-tannin (red sorghum)

[2] Cowpea variety (Bechuana white) were used

[1] Figures in brackets are baker's percentages based sorghum or sorghum and cowpea flours

Sugar and sunflower oil were creamed for 3 min starting at minimum speed and gradually increasing to speed 3 using a Kenwood Electronic Chef Excel with a K-beater attachment (Kenwood Maraisburg, South Africa). The dry ingredients (flour and baking powder) were mixed and added to the creamed mixture, mixed for 1 min, and then vanilla essence and water were added, and mixed for 3 min at speed 3 to obtain a firm dough. The dough was halved, rolled to a thickness of ±5 mm using a rolling pin on lightly greased aluminium foil and cut into 40 mm squares with a multi-square wire cutter, which gave a final dry biscuit of approx. 10 g. Each dough piece was pricked with seven holes using a knife to release moisture and prevent the biscuits from cracking during baking. The aluminium foil with the biscuit dough pieces were transferred onto a baking tray and baked in a pre-heated steam convection oven (Unox, Padova, Italy) set at 190 °C for approx. 20 min, until visually fully baked. After cooling at ambient temperature, the biscuits were packaged in polyethylene zip-lock bags, and stored at 6 °C. For the chemical analyses, the biscuits were ground using a mortar and pestle to a particle size of ≤ 500 µm.

Proximate analyses

Analyses were performed according to AACC International approved methods.[12] Moisture content was determined by method 44-15A (one stage drying), ash by method 08-01, protein (sorghum and cowpea N × 6.25) and wheat biscuits (N × 5.70) by Dumas combustion method 46-30 and crude fat by Soxhlet extraction method 30-25.

Starch content was determined by the Megazyme Total Starch Assay Procedure Amyloglucosidase/α-Amylase method.[13] Dietary fibre content of the flours was calculated by difference from the sum of the ash, protein, fat and starch contents, and that of biscuits also by difference but including the weight of added sugar. Energy was calculated using Atwater conversion factors.[14]

In vitro protein digestibility (IVPD)

A pepsin protein digestibility assay method was used.[15] Samples were digested with porcine pepsin P7000-100G for 2 h at 37 ºC. The residual protein was determined by Dumas combustion and IVPD was calculated as the difference between the initial weight of protein and the residual weight of the protein after pepsin digestion, and expressed as percentage of the initial weight of protein.

Trypsin inhibitor activity

Trypsin inhibitor activity was determined according to AACC International method 22-40.[12] Defatted soya bean flour was used as standard.

Instrumental evaluation of colour and texture of biscuits

Colour

The L* a* b* colour values of biscuits was measured using a CR 210 Minolta Chromameter model CR-400 (Osaka, Japan). Three readings of the L* a* and b* values were taken at three positions on the top of three randomly selected biscuits from each treatment.

Texture

Biscuit textural analysis was performed using a TA.XT2 Textural Analyser (Stable Microsystems, Godalming, UK). The maximum peak force during the first compression (hardness) and the distance compressed before breaking (fracturability) were measured using a three point bend rig (attachment HDP/3PB), comprising an upper blade with two adjustable supports adjusted to 28 mm. The test speed was 3.0 mm/sec. Three replicate analyses for each treatment were performed. The fracture properties of the biscuits were determined: [16]

$$\sigma = \frac{3FL}{2bh^2}, \ \varepsilon = \frac{6h}{L^2}$$

Where σ is the stress at midpoint (Mpa), ε is the strain, F the force at the beam centre (N), L is the distance between the supports (mm), b is the biscuit width (mm) and h is the biscuit thickness (mm). Stress was expressed as kPa and strain as percentage.

Consumer sensory profiling and acceptance evaluation of the biscuits

A total of 97 consumers (74 % female and 23 % male), 18 to 55 years, recruited in the Mamelodi suburb of the Tshwane metropole, South Africa, participated in the consumer study. The evaluation took place in a central location venue, namely a lecture hall of the University of Pretoria’s Mamelodi campus. A person familiar with the community structure in the area, who was briefed to recruit only resource-constrained, low-income consumers,[17] recruited the consumers.

On the day of the evaluation, the reason for the evaluation and procedures to follow was explained to the group, both in English and in local vernaculars, eg. Sesotho, Isizulu. English was used on evaluation forms as it is a common language of communication in South Africa where 11 official languages are recognized.[18] However, due to limited English and general literacy skills of some of the consumers, student helpers familiar with different verniculars were available to assist individuals. Consumers were informed about the purpose of the study and were told beforehand that the activity consisted of tasting six biscuits that may contain wheat, cowpeas, sorghum, oil, sugar and flavourants. Participants were briefed on the procedures and written informed consent was obtained prior to participation. Participants received a store voucher of ZAR 50 at the end of the session.

Each consumer received six biscuits, i.e. one biscuit from each of the treatments, individually packed in 100 mm × 80 mm zip-lock plastic bags labeled with three-digit random numbers. The order for presenting the biscuits followed a Williams design generated using Compusense Five 5.2 (Compusense Guelph, ON, Canada). Water was served as a palate cleanser before and between tasting the biscuits.

Consumers were first asked to look and smell each biscuits and to complete a CATA questionnaire comprising nine aroma terms (Table 2). They were then asked to taste each biscuit and select all the attributes that described that biscuit from a list of 30 flavour and texture terms (Table 2). The CATA terms were generated from previous related sensory research on sorghum and cowpea products.[4,7,19,20]

Table 2: Contingency table (%) for the CATA evaluation for whole grain sorghum, wholegrain sorghum-cowpea and wheat biscuits. (n = 97 consumers)

Terms	Sorghum biscuits		Composite biscuits		Standard wheat biscuits	
	White sorghum	Red sorghum	White sorghum: Cowpea	Red sorghum: Cowpea	Shortbread	Original
Evaluation of smell of biscuits before consumption						
Baked biscuits[n.s.]	73	72	74	70	82	79
Butter*	42	36	47	49	65	48
Sweet*	43	39	46	43	74	73
Heated oil*	39	42	32	40	27	24
Mabele (sorghum)*	46	47	40	44	15	11
Plant/grass[n.s.]	13	12	12	13	5	7
Beany*	11	13	21	19	5	4
Spices*	9	8	9	7	11	26
Herbs*	15	13	14	9	6	25
Evaluation of texture and flavour of biscuits						
Rough*	52	51	44	42	32	34
Soft*	4	12	43	33	24	24
Hard*	72	66	32	47	70	52
Crunchy[n.s.]	47	46	50	48	42	51
Dense, thick, compact[n.s.]	20	26	16	18	28	21
Moist[n.s.]	9	9	14	20	14	14
Dry*	72	68	57	54	58	55
Crumbly[n.s.]	27	26	25	21	19	23
Chewy[n.s.]	31	35	37	39	42	38
Bitter[n.s.]	10	14	9	15	10	12
Burnt[n.s.]	16	15	11	9	12	7
Mabele (sorghum)*	43	45	34	43	11	8
Nutty*	12	18	41	29	10	8
Roasted[n.s.]	26	29	26	24	22	19
Soy, *Pronutro*[3n.s.]	21	14	22	20	15	10
Sweet*	27	41	43	25	65	66
Vanilla*	18	20	19	13	43	19
Caramel[n.s.]	11	9	19	13	18	15
Ginger*	10	11	14	12	15	63
Cinnamon*	11	7	10	7	9	19
Coconut[n.s.]	22	21	20	24	20	16
Spices[n.s.]	7	6	6	8	9	15
Herbs*	9	7	17	7	3	13
Medicinal[n.s.]	4	5	5	3	2	5
Doughy (dough)[n.s.]	11	7	8	3	7	5
Beany (beans)*	11	9	13	16	7	3
Peanut butter*	17	16	27	25	19	9
Bland (no taste)*	20	23	15	20	6	3
Gritty, grainy, sandy*	23	24	27	35	8	8

[n.s.]no significant difference ($p \geq 0.05$). *significant difference ($p < 0.05$) according to Friedman's test-attributes bold print. [1]Pronutro: an instant cereal-soy composite breakfast porridge.

Consumers were also asked to indicate the acceptability of the biscuits using a structured 9-point hedonic scale, ranging from 'dislike extremely' to 'like extremely', and to qualify their purchase intent using another 5-point scale, ranging from 'definitely would not buy' to 'definitely would buy'.

Statistical analyses

The effect of biscuit type on nutritional, colour, texture measurements and overall liking ratings were analysed using one-way analysis of variance (ANOVA) and the least significant difference LSD test for means separation. The frequency of checking each term on the CATA lists was determined for each type of biscuit. Friedman's test considering biscuits as source of variation was used to determine differences in consumers' perception of the biscuits.[10] Correspondence Analysis (CA) was performed on the CATA frequency counts, average overall liking scores, colour and texture measurements.[21] To identify groups of consumers with similar preference patterns, cluster analysis using agglomerative hierarchical clustering with Ward's method clustering for dissimilarity of Euclidian distance was performed on the overall liking data (only data sets where individual consumers provided ratings for all 6 biscuits, were included). Separate per cluster one-way ANOVA models was used to determine the effect of biscuit type on liking ratings. XLSTAT Version 2015.3.01.19790 (Addinsoft, New York, United States) was used.

RESULTS AND DISCUSSION

Proximate composition

Except for protein content which was slightly higher in the red sorghum flour and biscuits, there was little difference in proximate composition between the white and red whole grain sorghum flours and their biscuits (Table 3). However, in line with USDA National Nutrient Database data,[24] the protein, ash (mineral) and dietary fibre contents of whole grain cowpea was much higher than that of whole grain sorghum and the fat and starch contents much lower. Compositing whole grain sorghum and cowpea at a 60:40 ratio substantially increased the ash and protein contents of the biscuits when compared to 100% sorghum biscuits (Table 3). The mineral content of the composite biscuits was 40% higher than that of 100% sorghum biscuits. This is because cowpea is rich in iron, potassium, calcium and sodium (USDA National Nutrient Database for Standard Reference Release 28 (https://ndb.nal.usda.gov/ndb/search/list)). The ash content of the 100% sorghum biscuits was, however, similar to that of the commercial wheat biscuits. This was presumably due to added salt in the commercial wheat biscuits as whole grain sorghum has a considerably higher mineral content than refined wheat flour (USDA National Nutrient Database for Standard Reference Release 28 (https://ndb.nal.usda.gov/ndb/search/list)).

The protein content of the composite biscuits was 50-60% higher than that of 100% sorghum biscuits due to inclusion of the protein-rich cowpea (Table 3). However, the protein content of the composite biscuits did not differ from that of the wheat biscuits. This is because wheat generally has higher protein content than sorghum (USDA National Nutrient Database for Standard Reference Release 28 (https://ndb.nal.usda.gov/ndb/foods/show/4799). The higher fat content of the 100% sorghum and sorghum-cowpea composite biscuits compared to the wheat biscuits (20-21%) versus 15-18% was due to the inclusion of 16% sunflower oil (Table 1). However, this did not result in the sorghum or sorghum-cowpea biscuits having a higher energy content than the commercial wheat biscuits. This is because the higher oil content of the former was compensated by the much lower dietary fibre content of the latter. Nevertheless, a 30 g serving of the biscuits would provide approximately 570 kJ, some 7% of a 9-10 year old child's energy requirements.[23]

Table 3 Proximate composition of whole grain sorghum and cowpea grain and flours, their composite flours and biscuits made from these flours and wheat biscuits (g/100 g)

Flours/Biscuits	Composite ratio	Moisture	Ash	Protein[2]	Fat	Starch	Dietary fibre[3]	Energy[4] (kJ/g 100 g
Flours								
White sorghum		12.27[j] ± 0.11	1.59 ± 0.06 (1.82)[f 1]	7.60 ± 0.20 (8.67)[d]	3.04 ± 0.05 (3.46)[d]	65.0 ± 1.7 (74.1)[e]	10.5	1347
Red sorghum		10.52[f] ± 0.06	1.29 ± 0.11 (1.45)[d]	8.96 ± 0.05 (10.01)[g]	3.21 ± 0.01 (3.59)[d]	65.5 ± 2.6 (73.2)[bc]	10.5	1385
Cowpea		11.60[h] ± 0.04	3.45 ± 0.07 (3.91)[i]	19.78 ± 0.12 (22.37)[i]	0.92 ± 0.01 (1.04)[a]	39.6 ± 1.6 (44.8)[bc]	24.6	1044
White sorghum:Cowpea	60:40	12.02[i] ± 0.07	2.47 ± 0.05 (2.81)[h]	12.99 ± 0.07 (14.76)[h]	2.39 ± 0.10 (2.71)[c]	54.8 ± 1.8 (62.2)[d]	15.3	1240
Red sorghum:Cowpea	60:40	11.02[g] ± 0.07	2.36 ± 0.15 (2.66)[g]	13.17 ± 0.03 (14.80)[h]	2.12± 0.11 (2.39)[b]	55.2 ± 1.2 (62.1)[d]	16.1	1240
Biscuits								
White sorghum		1.71[c] ± 0.05	1.34 ± 0.03 (1.36)[cd]	5.21 ± 0.05 (5.30)[a]	20.55± 0.06 (20.91)[gh]	45.9 ± 0.2 (46.7)[c]	9.2	1903
Red sorghum		1.72[c] ± 0.03	1.11 ± 0.04 (1.31)[a]	6.06 ± 0.02 (6.16)[b]	20.39± 0.39 (20.75)[g]	44.2 ± 2.7 (45.0)[bc]	10.4	1883
White sorghum:Cowpea	60:40	1.31[a] ± 0.01	1.73 ± 0.03 (1.76)[ef]	8.51 ± 0.11 (8.61)[cd]	20.66± 0.11 (20.93)[gh]	40.6 ± 0.4 (41.2)[a]	11.6	1873
Red sorghum:Cowpea	60:40	1.61[b] ± 0.01	1.65 ± 0.01 (1.67)[e]	9.08 ± 0.11 (9.23)[e]	21.77± 0.12 (21.11)[h]	39.8 ± 0.2 (40.4)[a]	10.0	1911
Wheat Shortbread standard		6.10[d] ± 0.03	1.20 ± 0.01 (1.28)[bc]	8.93 ± 0.16 (9.51)[f]	15.06± 0.04 (16.04)[e]	39.1 ± 0.3 (41.7)[ab]	1.1[5]	1856
Wheat Original standard		6.29[e] ± 0.04	1.15 ± 0.03 (1.22)[ab]	7.92 ± 0.14 (8.45)[c]	18.07± 0.07 (19.29)[f]	40.1 ± 0.7 (42.8)[ab]	1.1	1915

[1]Values are mean ± standard deviation, (mean dry flour or biscuit basis). n = 3. Values in a column followed by different letter superscripts are significantly different ($p < 0.05$).
[2]Calculated using N × 6.25 for sorghum and cowpea, and N × 5.70 for wheat.
[3]Calculated by difference [for flours = 100-(ash + protein + fat + starch) and for biscuits = 100-(ash + protein + fat + starch + sugar).
[4]Calculated using the following conversion factors: protein 17 kJ/g, fat 37 kJ/g and carbohydrates 17 kJ/g.
[5]South African Medical Research Council (1991) data

Concerning dietary fibre, as indicated the fibre content of the whole grain sorghum and sorghum-cowpea composite biscuits (9.2-11.6 %) was far higher than that in the commercial refined wheat biscuits, containing only 1.1 % (Table 3). Hence, a 30 g serving of the whole grain biscuits would provide some 10 % of the recommended dietary intake for dietary fibre, approximately 30 g.[24]

Protein quality

In comparison with defatted soy flour, whole grain cowpea flour had a very low level of trypsin inhibitor activity and trypsin inhibitor activity was not detectable in either the whole grain sorghum or sorghum-cowpea composite flours or biscuits (Table 4). However, the IVPD of the sorghum biscuits was very low, only 28-34 %. This is because sorghum protein digestibility is notably reduced when heated in the presence of moisture as a result of disulphide cross-linking.[25] Inclusion of globulin protein-rich whole grain cowpea flour considerably increased the IVPD of the biscuits to 50-58 %, but the digestibility of the biscuits was still considerably lower than that of the wheat biscuits (95 %). Nevertheless, due to cowpea protein being very rich in lysine (6.8 g/100 g protein) (USDA National Nutrient Database for Standard Reference Release 28 (https://ndb.nal.usda.gov/ndb/foods/show/4799), the first limiting essential amino acid in cereals, the overall protein quality of the sorghum-cowpea composite biscuits in terms of calculated protein digestibility corrected amino acid score (PDCAAS) was as good as that of the wheat biscuits, approximately 0.45.

Colour and textural properties of biscuits

Red sorghum biscuits had lower L* values (were darker) and higher a* values (more red) than white sorghum biscuits (Table 5). Sorghum-cowpea composite biscuits were slightly lighter and less red than 100% sorghum biscuits. However, the sorghum and sorghum-cowpea biscuits were darker and much less yellow (lower b*) than the commercial wheat

Table 4 Trypsin inhibitor activity (TIU), pepsin in-vitro protein digestibility (IVPD) and calculated protein digestibility corrected amino acid scores (PDCAAS) of whole grain sorghum and cowpea flours, their composites and biscuits made from these flours and wheat biscuits

		TIU/g (db)		IVPD (%)		PDCAAS[3]	
	Composite ratio	**Flours**	**Biscuits**	**Flours**	**Biscuits**	**Flour**	**Biscuits**
White sorghum		Not detected	Not detected	74.4[f] ± 0.6[1]	33.9[b] ± 0.9	0.33	0.15
Red sorghum		Not detected	Not detected	65.4[e] ± 4.0[1]	27.8[a] ± 0.9	0.29	0.12
Cowpea		6857 ± 1330[2]	Not applicable	94.8[i] ± 0.2	Not applicable	0.95	Not applicable
Raw defatted soy standard		86588 ± 3514[2]	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
White sorghum:Cowpea	60:40	Not detected	Not detected	85.9[h] ± 0.8	58.0[d] ± 0.0	0.71	0.48
Red sorghum:Cowpea	60:40	Not detected	Not detected	79.6[g] ± 2.3	50.3[c] ± 0.1	0.66	0.42
Wheat Shortbread standard		Not applicable	Not detected	Not applicable	96.4[i] ± 0.2	Not applicable	0.46
Wheat Original standard		Not applicable	Not detected	Not applicable	95.4[i] ± 0.4	Not applicable	0.46

[1] Values are mean ± standard deviation, n = 2. Means followed by different letter superscripts are significantly different ($p < 0.05$).

[2] Values are mean ± standard deviation. n = 3.

[3]Calculated using lysine score of 48 mg/kg protein for 3-10 year olds (WHO/FAO/UNU Expert Consultation, 2007) using USDA (2011) lysine values for sorghum grain (20067), cowpeas (black eyed bean, 16062) and wheat flour (unbleached enriched white flour 11.5% protein, 20636) x pepsin IVPD.

Table 5 Colour and texture properties of whole grain sorghum, sorghum-cowpea composite biscuits and wheat biscuits

	Composite ratio	L*	a*	b*	Hardness (N)	Fracturability (mm)	Stress (kPa)	Strain (%)
White sorghum		50.4^{b} ±0.2[1]	6.6^{b} ± 0.0	17.7^{b} ± 0.2	7.2^{a} ± 0.2	0.6^{a} ± 0.2	417.3^{b} ± 9.9	1.8^{a} ± 0.8
Red sorghum		48.7^{a} ± 0.4	12.5^{f} ± 0.3	16.4^{a} ± 0.4	17.3^{b} ± 6.2	0.9^{b} ± 0.1	767.8^{d} ± 61.0	3.1^{b} ± 0.0
White sorghum:Cowpea	60:40	55.5^{d} ± 0.1	5.4^{a} ± 0.3	18.8^{c} ± 0.4	30.8^{d} ± 0.1	1.1^{bc} ± 0.2	1616.9^{e} ± 52.2	3.4^{b} ± 0.5
Red sorghum:Cowpea	60:40	53.5^{c} ± 0.5	8.6^{c} ± 0.1	17.2^{ab} ± 0.3	18.9^{bc} ±0.4	0.8^{ab} ± 0.1	627.3^{c} ± 20.6	3.1^{b} ± 0.4
Wheat Shortbread standard		66.3^{e} ± 0.8	10.7^{e} ±0.5	31.1^{e} ± 0.8	23.6^{c} ± 1.1	1.7^{d} ± 0.0	278.3^{a} ± 17.3	13.0^{d} ± 0.9
Wheat Original standard		66.8^{e} ± 0.2	9.3^{d} ±2.4	29.7^{d} ± 0.5	36.4^{d} ± 0.0	1.3^{c} ± 0.0	412.9^{b} ± 79.3	9.2^{c} ± 0.3

[1] Values are mean ± standard deviation, n = 3. Means followed by different letter superscripts in the same column are significantly different ($p < 0.05$).
L*: indicates lightness where 0 = darkness and 100 = lightness.
a*: indicates redness where –a* = greenness and +a* = redness.
b*: indicates yellowness where –b* = blue and +b* = yellow.

biscuits. This characteristic colour of the whole grain sorghum and sorghum-cowpea biscuits is primarily due to the pigmentation of the sorghum pericarp, which is caused by polyphenols.[26]

There was no consistent pattern with regard to the strength (measured as stress by instrumental texture analysis) of the whole grain sorghum and sorghum-cowpea biscuits. Generally, they had higher stress values than the wheat biscuits (Table 5). Fonio-cowpea composite biscuits were stronger (higher stress) than 100 % wheat biscuits.[27] It was suggested that the soluble globulins of cowpea with fonio components may have contributed to the stronger texture. The sorghum-based biscuits were, however, much more brittle (approximately 2-3 % strain) than the wheat biscuits (approximately 9-13 % strain). The brittleness is presumably largely a result of the absence of gluten in the sorghum-based biscuits.

Consumer evaluation

Table 2 shows the frequencies for each CATA descriptive term checked by the consumers for the different biscuits. The most frequently selected aroma attributes were baked biscuit, sweet, butter, heated oil and mabele (sorghum). The most used texture attributes were hard, dry, crunchy, rough and chewy, and flavour attributes were mabele and sweet. The least used flavour attributes were medicinal, doughy, spice and herbs.

Twenty two of the 38 attributes, related mainly to description of the flavour, significantly differentiated ($p < 0.05$) the biscuits. For example, consumers differentiated the different types of biscuits on the presence or absence of mabele, nutty, vanilla and beany flavours. However, the attributes baked biscuit aroma and plant/grass aroma, crunchy, dense, crumbly and chewy textures, and bitter, burnt, roasted, soy/*ProNutro* (instant cereal-soy composite breakfast porridge), caramel, medicinal and doughy flavours did not differentiate the biscuits.

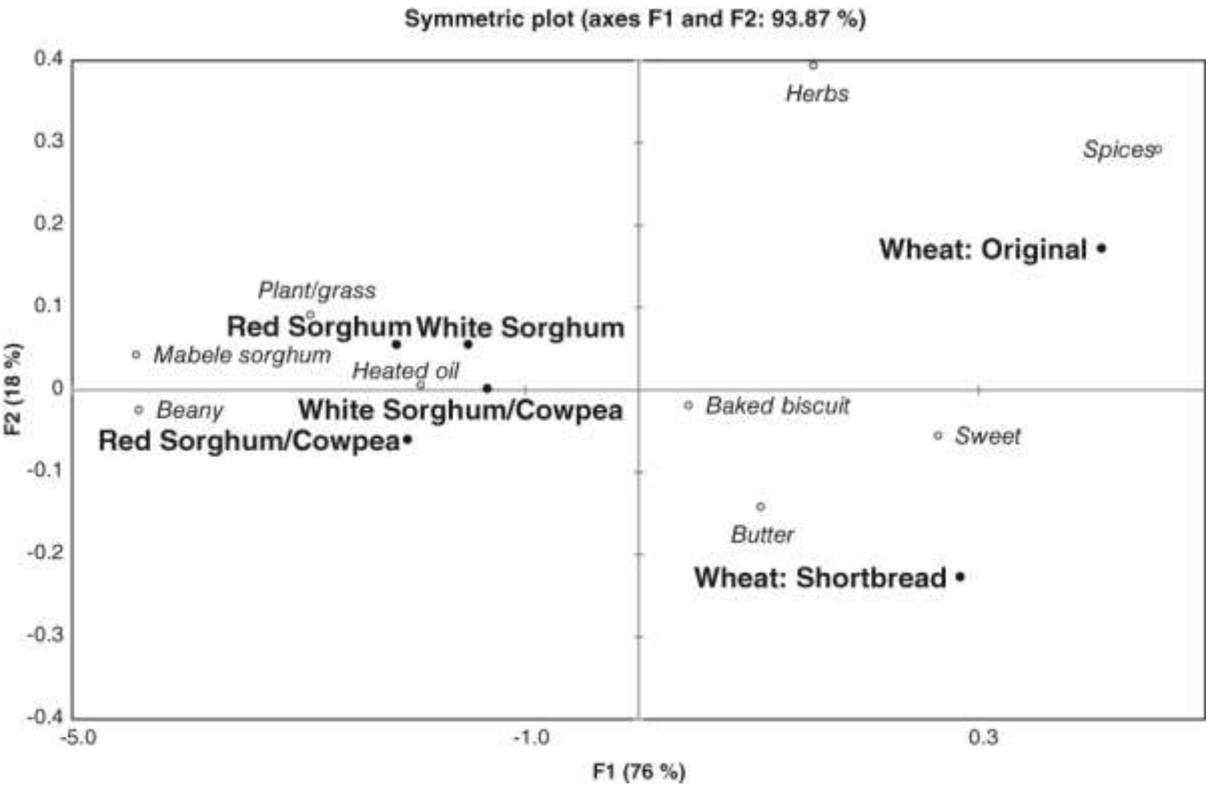

Figure 1 Representation of the biscuits (sorghum, sorghum-cowpea and wheat standards) and the aroma terms in the first two dimensions of the correspondence analysis (CA) performed on consumers' responses to check-all-that-apply (CATA) question

Figure 1 shows the representation of the biscuits on the first two CA dimensions with respect to aroma attributes. Dimension 1 explained 76% of the total variation and separated biscuits by the type of cereal used with the sorghum and sorghum-cowpea biscuits to the left and wheat biscuits to the right. Dimension 2 represented an additional 18% of the variation and clearly separated the shortbread wheat biscuit at the bottom with butter and sweet aroma from original wheat biscuits at the top with more prominent spice and herb aroma.

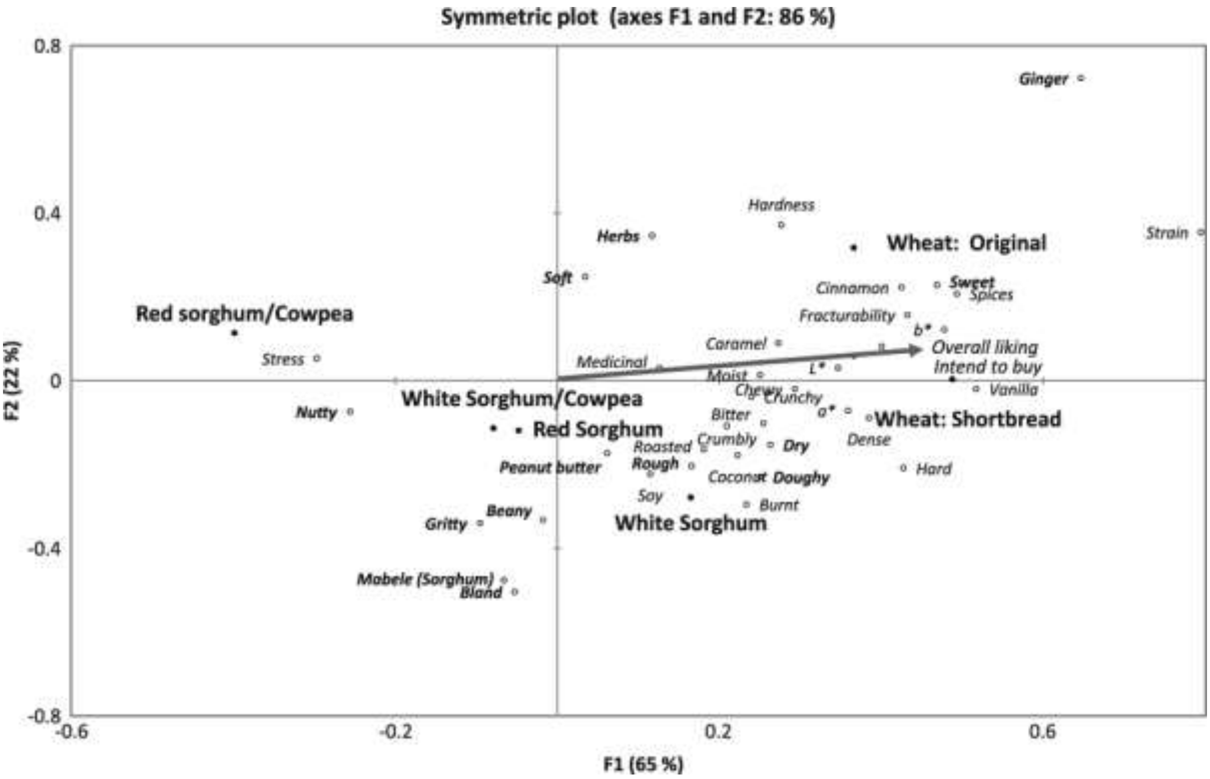

Figure 2 Representation of the biscuits (sorghum, sorghum-cowpea, wheat standards) and the texture and flavour terms in the first two dimensions of the correspondence analysis (CA) performed on consumers' responses to check-all-that-apply (CATA) questions, including instrumental data, consumers' overall liking and intent to buy data

Figure 2 shows the CA for the descriptive attributes while consuming the biscuits, colour and texture analyses as well as hedonic and intention to buy ratings. The first two dimensions accounted for 87% of the variation among the biscuits. Dimension 1 explained 65% of the variation and separated biscuits based on the type of cereal used, with wheat biscuits to the left displaying higher strain, with ginger and vanilla sweet flavours and the sorghum and sorghum-cowpea biscuits to the right characterised by higher stress with nutty flavour. Dimension 2 explained a further 22% of the variation and separated the sorghum biscuits based on the presence or absence of cowpea flavour. Sorghum only biscuits, were characterized by being hard, rough, gritty, dry in texture with clear mabele flavour, while sorghum-cowpea biscuits had a more nutty flavour. The two wheat biscuits were also distinguished on this dimension with ginger flavour more prominent in the original type. Badi and Hoseney[28] similarly reported that sorghum biscuits had a harder texture compared to wheat biscuits. The gritty and rough characteristics of sorghum biscuits has been widely reported.[4,28,29] The grittiness of sorghum flour products is associated with the grain having a corneous (hard) endosperm.[30] Serrem *et al*.[4] also noted the dry texture of sorghum biscuits, which was attributed to the hydrophobic nature of kafirin proteins of the endosperm.[25]

As stated, consumers also related beany and peanut butter flavour with the sorghum and sorghum-cowpea biscuits. The beany flavour, also described as peanut butter by consumers in this study is associated with legumes. A beany flavour was reported in sorghum-cowpea composite porridge.[19] In another study,[31] furans were identified in wheat cookies substituted with soy protein isolate. Singlet oxygen ($^1O_2$) is involved in the formation of pentylfuran and pentenylfuran from linoleic and linolenic acids described as contributing beany flavour to soybean oil.[33] Furan formation may also be due to thermal degradation/Maillard reaction of reducing sugars, thermal degradation of certain amino acids, and thermal oxidation of ascorbic acid, poly-unsaturated fatty acids and carotenoids.[33]

Interestingly, hardness by texture analysis and the CATA attribute hard used by consumers was not positively correlated (Figure 2). This was probably due to the difference in the way hard texture was measured by the instrument and consumers. Hardness, as measured instrumentally, is defined as the maximum peak force during the first compression, i.e. the force required to snap a biscuit (simulating a first bite), which was found to be higher for wheat biscuits than the others (Table 5). However, the hard texture as perceived by consumers (Table 2) is not only related to the first bite but may include a combination of various oral tactile sensations, among which touch by lips, chewing and breakdown of the biscuits.[34]

Wheat biscuits had higher L* and b* values, whereas red sorghum and red sorghum-cowpea biscuits had higher a* values. From Figure 2 it is evident that lighter (L*), more yellow (b*) biscuits with ginger, vanilla, sweet and cinnamon flavours and with higher fracturability scores were positively correlated with overall liking and intent to buy. These attributes described the wheat biscuits and could thus be considered as drivers of overall liking and buying intention.

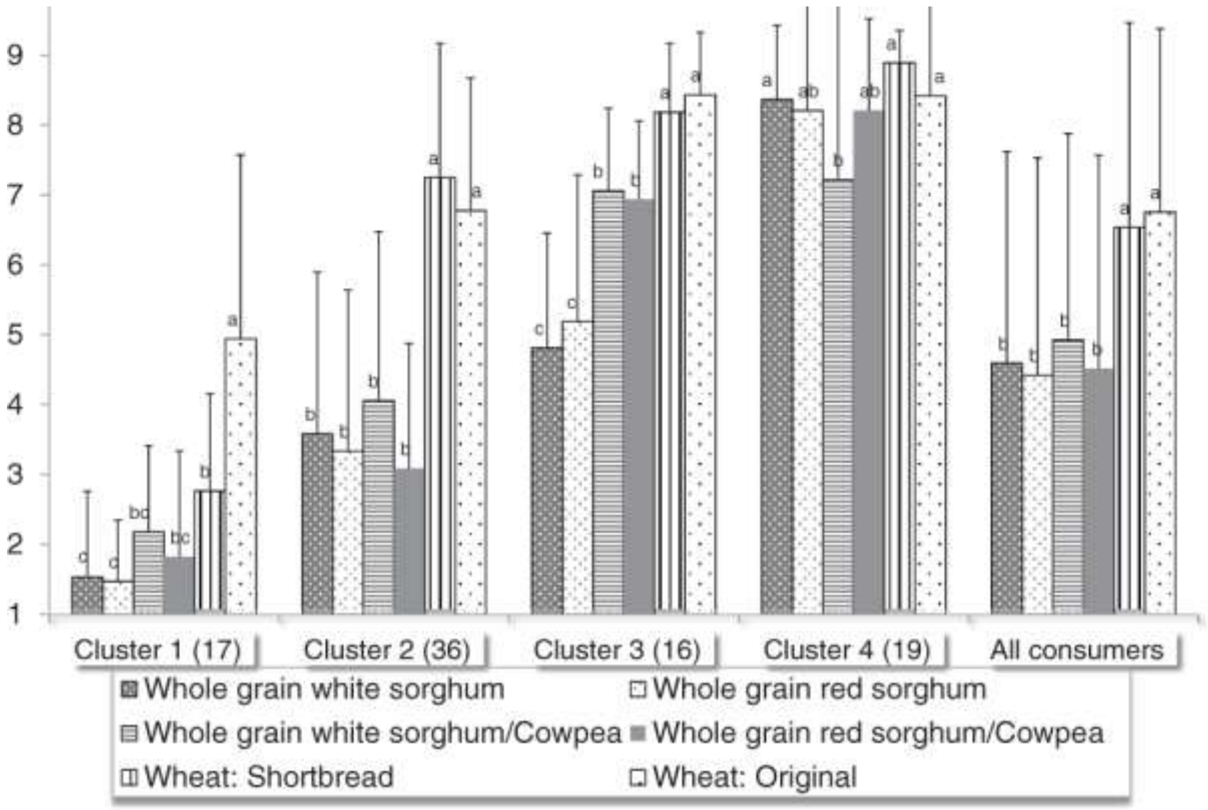

Figure 3 Mean overall liking ratings for sorghum, sorghum-cowpea and wheat biscuits by clusters of consumers with different liking patterns. Clusters are based on complete sets of ratings for all six biscuits from n=88, while the comparison of liking ratings for all consumers is based on n=97 consumers.

Vertical bars = ± standard deviations. Scores were evaluated on a 9-point hedonic scale (where 1 = dislike extremely and 9 = like extremely).

abc Mean ratings within cluster groupings with different letters, differ significantly ($p < 0.05$)

Using cluster analysis, four groups of consumers with different liking patterns for the biscuits were identified (Figure 3). A maximum of four groups was considered since the smallest groups represented 16 and 17 participants, respectively. Among the groups, liking of biscuits differed significantly ($p<0.001$). The largest group of consumers, cluster 2, ($n = 36$) consumers preferred the original and shortbread wheat biscuits over sorghum and sorghum-cowpea biscuits. Cluster 4 (19 consumers) gave relatively high scores for all biscuits. Cluster 1 consumers ($n = 17$) disliked all biscuits with the exception of the ginger flavoured original wheat biscuit ($F = 11.7$; $p <0.001$). Cluster 3 consumers ($n =16$) gave significantly higher liking ratings for the wheat biscuits than the whole grain sorghum-cowpea biscuits, while 100 % sorghum biscuits were liked the least ($F = 18.7$, $p < 0.001$).

Considering all consumers, the wheat biscuits were significantly better liked ($F = 12.3$, $p < 0.0001$) than the sorghum and sorghum-cowpea biscuits. A study relating responses to familiar and unfamiliar foods,[38] found that most consumers prefer to consume familiar foods. This may explain the higher liking for wheat biscuits. In contrast, there was a substantial percentage of consumers (40%), in clusters 3 and 4, that gave positive liking ratings for the sorghum-cowpea biscuits. The preference for sorghum-cowpea biscuits by certain consumers was possibly due to greater familiarity with sorghum and cowpeas. These consumers might have also liked the nutty flavour associated with sorghum-cowpea biscuits (Table 2). Yadav *et al*.[36] reported that wheat biscuits fortified with 15% de-oiled peanut meal flour were highly acceptable.

CONCLUSIONS

Compared to economic refined wheat biscuits, whole grain sorghum and sorghum-cowpea composite biscuits have much higher dietary fibre content and the composite biscuits have increased mineral content. Compositing with cowpea counteracts the low lysine level and poor digestibility of sorghum protein. This results in the overall protein quality of the whole grain sorghum-cowpea composite biscuits in terms of PDCAAS, being the same as wheat biscuits. Notwithstanding the absence of gluten, whole grain sorghum-based biscuits have similar strength to refined wheat biscuits but are somewhat more brittle.

The CATA method as applied here is suitable to rapidly determine which attributes low income consumers perceive in food products and relate these to reasons for differences in acceptability. Resource constrained, low-income, urban consumers, as included in this study, liked the lighter, more yellow wheat biscuits with ginger, vanilla, sweet and cinnamon flavours more than the stronger flavoured (sorghum, beany and nutty) and harder but brittle, grittier, with dry and rough textures sorghum or sorghum-cowpea biscuits. However, a substantial proportion of consumers also seem to like the sorghum-cowpea composite biscuits. These preliminary findings indicate that whole grain sorghum-cowpea biscuits could well serve as acceptable value-added nutritious complementary snack food for some low income consumers in some newly urbanized communities in sub-Saharan Africa. Further, because sorghum and cowpeas are widely grown in the region and the biscuits are simple to produce, such biscuits could be viable products for small enterprises.

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