Journal of Food Technology 9 (6): 143-149, 2011
ISSN: 1684-8462

Development of the Production Process for Sorghum Ice-Cream Cones

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Abstract: The demand for wheat has been increasing with the growth of baking industries in Uganda resulting in soaring prices of wheat flour and thus, a need to find alternative sources. Wheat was substituted completely with whole white sorghum flour (Epuripur variety) in a cone recipe and other ingredients varied to form different sorghum cones. The following parameters of the cones were measured; moisture content, weight, hardness, baking ability, head formation and as well as the functionality (ice-cream holding time). One way, two way and three way effects due to water increase, maize binder increase and reduction in sorghum particle size were found to be significant ($p<0.05$) but correlations between functionality (ice-cream holding time) and the cone parameters were found to be weak ($p<0.05$). The highest ranking sorghum cone in functionality held ice-cream for 22 min and remained crisp for at least 20 min was selected and tested for consumer acceptance against the commercial wheat cone using a panel of 31 people. Consumer acceptance testing was done using 2 types of successive category scales; a 9 point hedonic scale to rate appearance, color, flavor, texture and overall acceptability and the Food Action rating scale (FACT) scale measured acceptance by the frequency of eating measurement. The sorghum cone was rated higher than the commercial wheat cone in terms of texture, taste, overall acceptability and FACT ratings. Overall acceptability correlated highly with texture ($r^2 = 0.732$) and appearance ($r^2 = 0.65$). Based on these findings, it can therefore be concluded that the sorghum cone formulation was successfully produced, well accepted and can be adopted for production.

Key words: Sorghum, ice-cream cones, production, consumer acceptance, maize binder, Uganda

INTRODUCTION

The demand of wheat in Uganda is much higher than its supply and hence largely depends on imported wheat which makes up 90% of the wheat it consumes locally (Kamau and Katende, 2009). On the other hand, sorghum production in Uganda is well established and has been practiced across communities for centuries. Sorghum (*Sorghum bicolor* (L) *Moench*) is a staple cereal in Uganda with 490,000 metric tons being grown/annum (UBOS, 2010) as compared to wheat with 20,000 tons grown $annum^{-1}$. Sorghum is consumed predominantly as a primary commodity with little value addition as animal feed, human food (as porridge and gruel) and for traditional brewing (Byaruhanga and Auko, 2006). However, taking into account the direct and indirect effects, calculations show that growth in the sorghum subsector would generate higher gains in overall GDP of a country than would maize which is one of the highly demanded crops on the Eastern and Central African markets (Omamo *et al*., 2006). In addition, sorghum also is a good source of B vitamins, potassium and phosphorous and contains substantial levels of a wide range of phenolic compounds with health promoting properties such as antioxidant activity (Anglani, 1998; Taylor *et al*., 2006). As a result researchers in Uganda (UPMAS, 2008; HOPE, 2009) are working on increasing production of sorghum as well as the value chains that increase its utilization. Previous study proposed new food grade white sorghum hybrids as suitable for baking therefore potentially an alternative to wheat.

In the baking of ice cream cones the major ingredients are starch and water while minor elements include leavening agents, natural fibres proteins/natural polymeric compounds, emulsifying agents, sugar, salt and colour, starch being provided by cereal flours, preferably combined with pregelatinised or uncooked starches (Helou and Dellinger, 2007; Dautremonet *et al*., 2008).

Wheat flour is commonly used in the baking industry but millers say the demand for wheat flour has been increasing with the growth of the baking industries in Uganda and that the supply is not enough to feed the local and the international markets (Kamau and Katende, 2009). As a result the soaring wheat prices make the production of the wheat based cones challenging. In this regard, alternative sources of starch as could be provided by the new white sorghum hybrids are necessary for the survival of the baking industry.

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The challenge to overcome with sorghum flour is dryness in baked goods causing a coarser crumb, a generally drier taste and a product more inclined to crumble. This is because sorghum flour lacks gluten and therefore, does not have the same binding properties as wheat flour. According to Taylor *et al*. (2006) the use of sorghum flour for product development is challenged by its higher gelatinization temperatures, lack of gluten content and reactions of other proteins in the flour. However, according to Practically Edible and Twin valley mills, these challenges can be overcome by increasing the levels of water, starch, oil/fat, emulsifier, leavening agent, mixing times/mixing speeds and the use of xanthan gum as a binder but in amounts that have to be predetermined and specified. Cakes (sorghum flour/cassava; 70:30) and cookies (100% sorghum flour) have been successfully produced from sorghum while in bread making some challenges still remain but added ingredients especially methylcellulose, xanthan gum, rye pentosan and addition of pure starches (native and pregelatinized) were found to improve bread quality (Anglani, 1998; Taylor *et al*., 2006). Even when sorghum flour could serve as an alternative in cone making, there is no documentation on the production of sorghum cones thus the need for its development. A developed product though is commercially suitable if it meets the consumer acceptance (Salamoura, 2005). As such this research aims at exploring the use of new food grade white sorghum hybrids as a substitute for wheat in baking purposes especially in the production of ice cream cones and test them for consumer acceptability.

MATERIALS AND METHODS

About 80 kg Epuripur dry sorghum was obtained from Serere Agricultural and Animal Research Institute (SAARI), Serere district, Uganda. The grain was cleaned and sorted to remove any spoilt grain and any other foreign particles. It was milled using a Wonder mill at the highest level of fineness producing whole sorghum flour mean of particle size 120 μm. Commercial wheat flour (Bakhresa Grain Milling (U) Ltd., Uganda) randomly sampled from the open market was purchased and used for the control. Other ingredients; sugar (Kakira Sugar Works, Uganda), corn starch (American Garden Products, U.S.A), oil (Bidco Uganda Ltd., Uganda), sodium metabisulphite (NORBRIGHT IND, Co. Ltd., China), sodium bicarbonate (BIDCO oil Refineries, Kenya), ammonium bicarbonate DESBRO (U) Ltd. Uganda) were also randomly purchased from the local supermarkets.

Recipe formulation: The recipe used was according to ConWafer, 200 g wheat flour, 4 g maize starch, 3 g powdered sugar, 5 mL oil, 0.5 g soya lecithin, 1.06 g sodium and ammonium bicarbonate, 0.05 g sodium metabisulphite, 0.53 g salt, 320 mL water and desired food colour. The batter for a commercial wheat cone on the Ugandan market was also mixed and used as a control for the batter formation. The wheat in the ConWafer recipe was replaced with 100% sorghum flour and the other ingredients varied as such: maize starch (5,10, 20, 30, 40, 50 g), water (320, 350, 400, 425 and 450 mL) lecithin (0 tea spoon (tsp), 1/2, 1 and 2 tsp), sodium/ammonium bicarbonate (2, 3 and 4 g) and oil (5 and 7 mL) varied one at a time establishing their lower limits for the main ingredients and the upper limits for the minor ingredients until a well baked sorghum cone was achieved using a cone making machine at 200°C for the lower mould and 220°C for the upper mould. Dry ingredients were all first measured into a bowl and oil, lecithin, water added and mixing done using a Philips hand mixer at low speed until all ingredients were well mixed.

In view of improving the cone, the effect of further varying main ingredients by increasing water and binder as well as decreasing the particle size of the sorghum was studied using a 2×3 factorial experiment with water at two levels (350 and 400 mL), sorghum flour of two types (unsieved flour, sieved to a particle size of <250 μm and the binder, maize starch at two levels (60 and 70 g) resulting in eight cone formulations as shown in Table 1. All the other ingredients were kept constant, namely sugar at 40 g, oil at 7 mL oil, 1 teaspoon soya lecithin, 3 g of sodium and ammonium bicarbonate (50:50), 0.05 g of sodium metabisulphite and 0.53 g of salt. The batters were mixed and baked using a Gabrielli cone machine (Model MINICON 2) at 200°C for the lower mould and 220°C for the upper mould.

The resulting cones were analyzed in triplicate for their characteristics; moisture content, weight, probe penetration, baking ability, head formation and functionality (ice-cream holding time) and compared to a commercial wheat cone. The moisture content was measured using the oven method (AOAC, 2000), weight was measured using a laboratory scale and probe penetration was measured using a penetrometer. The baking ability was observed as the number of cones that were fully baked out of 10 cones for each baking round. The head formation was ranked on a scale of 1-10 for an average of 10 randomly selected cones. Ice cream holding time was measured at a commercial ice cream palour. The ice cream cones were placed on wooden racks and loaded

Table 1: Sorghum cone formulations

Formulations	Formulation code
Whole sorghum, 60 g maize starch, 350 mL water	WSM60W350
Whole sorghum, 60 g maize starch, 400 mL water	WSM60W400
Whole sorghum, 70 g maize starch, 350 mL water	WSM70W350
Whole sorghum, 70 g maize starch, 350 mL water	WSM70W400
Sieved sorghum, 60 g maize starch, 350 mL water	SSM60W350
Sieved sorghum, 60 g maize starch, 400 mL water	SSM60W400
Sieved sorghum, 70 g maize starch, 350 mL water	SSM70W350
Sieved sorghum, 70 g maize starch, 400 mL water	SSM70W350

with freshly made soft serve ice cream. The time taken for the ice cream to permeate to the surface until the cone was too soft to hold was measured in minutes as the ice-cream holding time. The best performing cone for ice cream holding time as compared to the commercial wheat cone was selected for sensory analysis.

Sensory analysis: An untrained consumer test panel (n = 31) was recruited from the School of Food Science, Nutrition and Bio-Engineering, Makerere University by polite solicitation. Panelists were selected based solely on interest, time availability and lack of allergies to food products used in the study. The sensory panel was used to determine the acceptability of the developed sorghum cones as compared to a commercial wheat cone. Sorghum cones were baked from recipe WSM60W350 as described previously and commercial wheat cones obtained from Ridar Cone, Kampala, Uganda. Consumer acceptance testing was done using 2 types of successive category scales. Panelists used a 9 point hedonic scale for sensory evaluation (9 = Like extremely; 8 = Like very much; 7 = Like moderately; 6 = Like slightly; 5 = Neither like nor dislike; 4 = Dislike slightly; 3 = Dislike moderately; 2 = Dislike very much; 1 = Dislike extremely) to rate the control and sorghum conefor appearance, color, flavor, texture and overall acceptability as described by Ramcharitar *et al.* (2005). The FACT (Food Action rating) scale measured cone acceptance by the frequency of eating measurement as described by Ramcharitar *et al.* (2005). The (FACT) scale values were as follows: 9 = I would eat his every opportunity that I had; 8 = I would eat this very often; 7 = I would frequently eat this; 6 = I like this and would eat it now and then; 5 = I would eat this if available but would not go out of my way; 4 = I do not like this but would eat this on an occasion; 3 = I would hardly ever eat this; 2 = I would eat this if there were no other food choices; 1 = I would eat this only if forced.

Data analysis: The effect due to increase in water, maize binder and decrease in sorghum particle size on the moisture content, weight, head formation, baking ability, penetration and ice cream holding capacity was determined using MINITAB 14 for factorial design for three factors at two levels. Means, standard deviations and standard errors were calculated for each of the sensory attributes and FACT rating scores for the comparison of the best sorghum cone and the wheat cone. Consumer panel results were also analyzed using paired t-tests for significance of mean differences and correlations between overall acceptability and other sensory attributes were computed using MINITAB 14. All analysis tests were performed at a significance level of 0.05.

RESULTS AND DISCUSSION

Replacement of wheat flour with 100% whole sorghum flour in the ConWafer recipe, resulted into a batter that could not hold together. The maize starch binder was increased until a stable batter was obtained at a level of 50 g, the water was increased until a batter of similar viscousity (18 dpas) to the control was obtained at 350 mL using a viscotester VT01. The baked cone failed with starch at 50 g so, the starch was increased to 60 g which formed a complete cone after baking but the cones were much heavier (14 g) than the control (8 g) so, the leavening agent was increased until a cone of similar heaviness to the control was achieved at 3 g. The levels of oil and lecithin were increased until the resulting cone structure begun to deform after baking so their levels were set below this upper limit at 1 level teaspoon and 7 mL, respectively. The sugar was also increased to 40 g to match that of the control. The resulting ConWafer recipe was thus modified to a working recipe of 200 g sorghum flour, 60 g maize starch, 40 g powdered sugar, 7 mL oil, 1 teaspoon soya lecithin, 3 g sodium and ammonium bicarbonate (50:50), 0.05 g sodium metabisulphite, 0.53 g salt, 350 mL water. The sorghum cones were found to bake faster (2.5 min) than the wheat cones (3 min), this could be attributed to the fact that Epuripur sorghum variety is moderately waxy and according to Del Pozo-Insfran *et al.* (2004), it has been suggested that waxy sorghums gelatinize more rapidly have a weaker protein matrix and are more susceptible to hydrolysis. The effect of further increasing the water level and binder level was studied as well as reducing the particle size of the sorghum flour in a factorial experiment by the formation of eight different combinations of these factors. Table 2

Table 2: Mean values of sorghum cone characteristics and ice-cream holding time

Parameters	Treatment code	MC_{wb} (%)	Wt (g)	Baking ability (%)	Head formation (ranked 1-10)	Probe penetration (mm)	Ice-cream holding time (min)
Formulation 1	WSM60W350	7.97	10.17	100	7	0.4	22
Formulation 2	WSM60W400	6.02	10.15	80	7	0.7	45
Formulation 3	WSM70W350	8.84	11.68	100	7	0.9	52
Formulation 4	WSM70W400	7.24	9.52	100	8	0.9	48
Formulation 5	SSM60W350	8.49	9.44	100	7	0.8	31
Formulation 6	SSM60W400	5.96	10.81	40	8	1.0	41
Formulation 7	SSM70W350	8.14	9.73	100	7	0.3	12
Formulation 8	SSM70W400	3.67	8.88	60	6	7.9	34
Control	Wheat	5.78	6.06	100	10	3.4	17

MC: Moisture Content, Wt: Weight

Table 3: Correlations: MC, ice-cream holding time, Wt, BA, HF, penetration

Characteristics	MC	Ice-cream holding time	Wt.	BA	HF
Ice-cream holding time	-0.170	-	-	-	-
Weight	0.417*	0.204	-	-	-
Baking ability	0.062	0.196	0.086	-	-
Head formation	0.247	0.382	0.135	0.101	-
Penetration	0.247	0.051	-0.500*	-0.086	-0.452*

*Significant at the 0.05 level. MC: Moisture Content, BA: Baking Ability, HF: Head Formation, Wt.: Weight

shows the results of the means of the cone characteristics and ice cream holding time of the cones from the eight formulations. Moisture content vs. weight, Penetration vs. weight and penetration vs. head formation showed significant correlation (Table 3).

Correlations between ice-cream holding time and the cone characteristics were generally weak (Table 3) surprisingly, especially with penetration which was a measure of cone hardness. This could be attributed to the two way and three way interactions between water level, starch level and the sorghum particle size (Fig. 1). This could be attributed to interactions between ingredients as well as sorghum proteins, kafirins that form structures with themselves or with other constituents during processing and/or cooking for example starch gelatinization, to directly impact functional properties and quality of sorghum-based foods (Hamaker and Bugusu, 2003; Ezeogu *et al*., 2005). Penetration (degree of hardness) correlated significantly negatively with weight and head formation.

The interactions due to effect of increasing maize starch, water and reducing the average particle size of the sorghum flour on the ice cream holding time are further shown in the Fig. 2. Increase in water (C), maize starch binder level (B) and decrease in sorghum particle size (A), had a significant effect ($p \leq 0.05$) on the moisture content, weight, baking ability, penetration and ice cream holding capacity of the cones (Fig. 1) as well as on the two way (AB, AC, BC) and three way interactions (ABC) between them. Head formation was significantly affected by interactions between sorghum particle size and binder level (AB) as well as interaction between all three factors (ABC) (Fig. 1).

In similar studies for the development of sorghum bread, changes in water and binder (xanthan gum) were also found to have effect on the bread crumb and volume; low viscosity of the batter system resulting in increased water levels and reduced levels of the xanthan gum all of which were found to improve bread quality (Olatunji *et al*., 1992). Further increase in water, maize starch binder level and decrease in sorghum particle size in formulation 1 (WSM60W350) did not produce

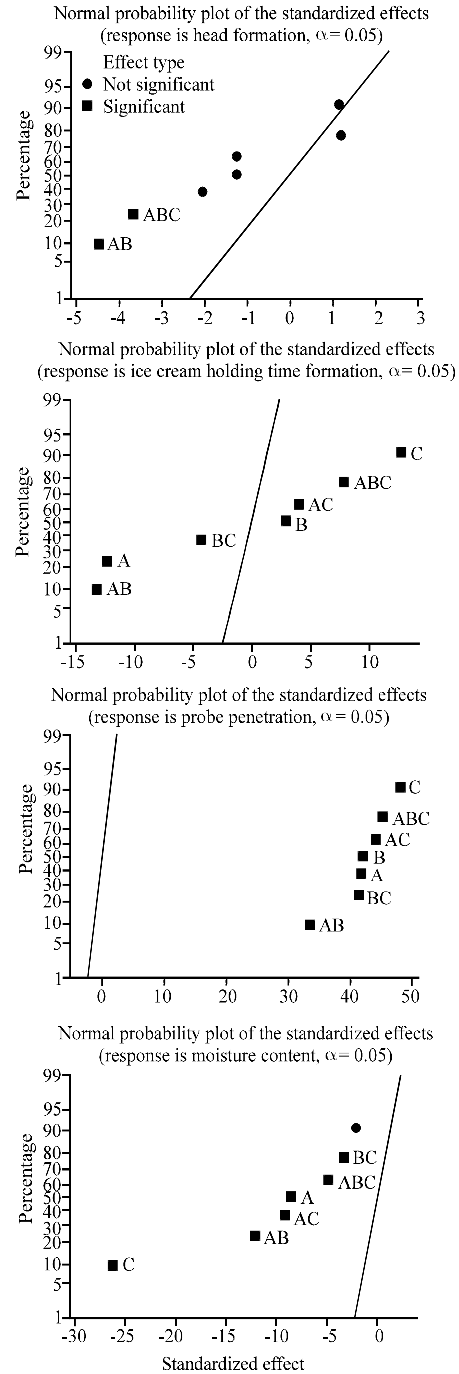

Fig. 1: Normal probability standardized effects of water, maize starch binder and decrease in sorghum particle size on moisture content, weight, penetration and ice cream holding capacity (A: Song, B: Binder level, C: water level)

cones with better functionality. Therefore, formulation 1 with functionality (ice cream holding capacity) closest

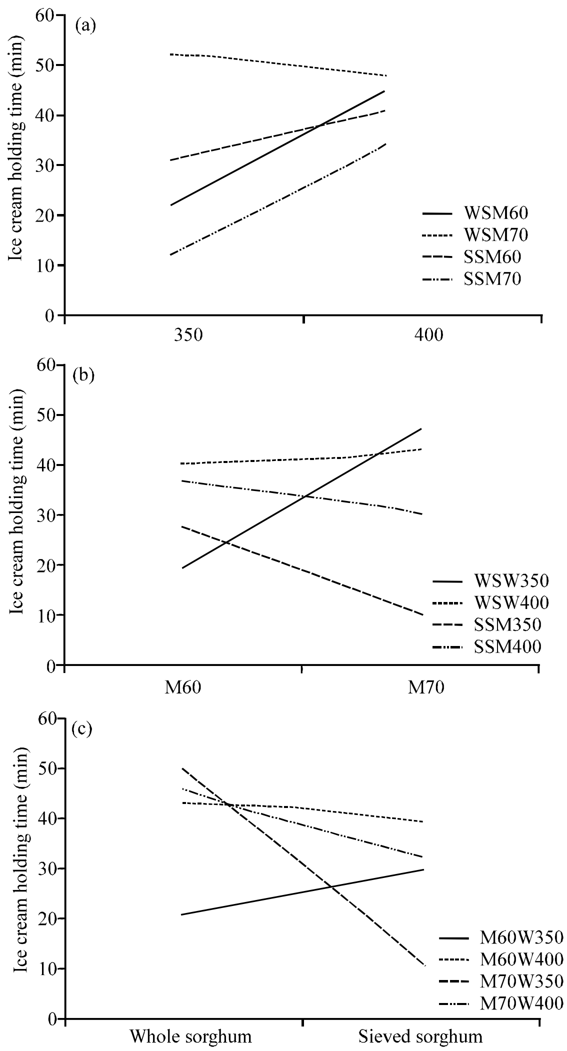

Fig. 2: Changes in ice-cream holding time due to a): water level, b): binder level and c): sorghum flour particle size

to the control, of 22 min was selected for the sensory analysis. It was able to hold ice cream longer by about 5 min more and remained crisp up to at least 20 min. The sorghum cone from formulation 1 when compared with the control (wheat cone) had more water, leavening agent, oil, starch binder and lecithin. These results are in agreement with those of Taylor *et al.* (2006) on sorghum bread which indicated that generally much higher water addition levels were required than wheat to allow for high dilution of all suspended particle. The researcher further points out that addition of pure starches in native or gelatinized form as in the sorghum cones also had positive effects on the bread making quality which could simply be a dilution effect i.e., endosperm and bran particles in the sorghum flour are diluted by the added starch which would be expected to disrupt the uniformity of the starch gel and interfere with the liquid films around the gas cells (Gan *et al.*, 1995; Moore *et al.*, 2004; Taylor *et al.*, 2006).

Table 4: Sensory attributes and overall acceptability of ice cream cones as rated by 31 untrained panelists ($p<0.05$)

Sensory attribute	Sorghum cone μ±SD (SE)	Wheat cone (control) μ±SD (SE)	Mean difference
Appearance[a]	6.387±1.542 (0.277)	7.433±1.547 (0.28)	-1.0300*
Texture[a]	7.100±1.470 (0.268)	5.900±2.234 (0.40)	1.1667*
Taste[a]	7.000±1.592 (0.286)	5.897±2.226 (0.41)	1.4330**
Color[a]	6.677±1.447 (0.260)	7.000±2.101 (0.38)	-0.3667
Overall acceptability[a]	7.103±1.589 (0.295)	5.964±2.168 (0.41)	0.9667

[a]Scale for all attributes: Range 9 = Like extremely to 1 = Dislike extremely (Ramcharitar *et al.*, 2005), [b]Food Action rating scale (FACT) scale rating: Range 9 = I would eat this every opportunity that I had to 1 = I would eat this only if forced (Ramcharitar *et al.*, 2005), *Significant at the 0.05 level, **Highly significant at the 0.05 level

Sensory analysis: Results form the sensory analysis showed that there were significant differences ($p<0.05$) between the ratings of the 2 cones with respect to appearance, texture, taste and FACT ratings (Table 3). Differences in the colour and overall acceptability were found not to be significant. The sorghum cone was rated higher than the wheat cone for texture, taste, overall acceptability and FACT ratings. The colour and appearance of the wheat cones were more preferred than those of the sorghum cones meaning that meaning that further research should work on improving the appearance and colour to make the sorghum cone more acceptable. The sorghum cone was rated as liked very much to liked moderately for overall acceptability and I would eat this frequently to I like this and would eat it now and then on the FACT scale (Table 4).

Results in Table 5 further show that for the sorghum cone, appearance was most strongly ($p<0.05$) correlated ($r = 0.856$) to overall acceptability which was followed by texture ($r = 0.806$). These results suggest the importance of optimizing the appearance and texture in future studies. For the wheat cone, taste was most strongly and positively correlated ($p<0.05$; $r = 0.701$) to overall acceptability (Table 4) implying that appearance and texture are key attributes for cone making. Other such studies including those of Morad *et al.* (1984) found that sugar cookies from sorghum flour had the highest spread factor relative to cookies from a commercial wheat cookie flour. Further more extruded sorghum snacks have been very successful in Japan due to their bland flavor, light colour and good expansion properties (Taylor *et al.*, 2006). Olatunji *et al.* (1992), successfully developed a cake recipe for a sorghum or millet/starch mixture although, it was found to be comparatively lean.

Table 5: Correlation of overall acceptability to sensory attributes of cones

	Overall acceptability	
Sensory attribute	Sorghum cone	Wheat cone (control)
Appearance	0.856**	0.261
Texture	0.806**	0.564**
Taste	0.671**	0.701**
Color	0.767**	0.254
FACT ratings	0.671**	0.812**

**Significant at the 0.01 level

CONCLUSION

Sorghum-based ice cream cones were successfully produced from formulation 1 using a cone making machine at 200°C for the lower mould and 220°C for the upper mould. Dry ingredients were all first measured into a bowl and oil, lecithin, water added and mixing done using a hand mixer until all ingredients were well mixed. The cones were able to adequately hold ice cream for 22 min and remained crisp up to at least 20 min. There was low correlation between the ice-cream holding time and the cone characteristics thus, the need for further investigation. The sorghum cone was rated higher than the wheat cone for texture, taste, overall acceptability and FACT ratings.

Thus, the parameters leading to these sensory attributes need to be maintained during manufacture of sorghum-based cones. The colour and appearance of the wheat cone were preferred implying that further research should be conducted to improve the appearance and colour to make the sorghum cones more acceptable. It can therefore be concluded that the sorghum cone was well accepted by the consumers and can be adopted for production.

ACKNOWLEDGEMENTS

Researchers would like to express the thanks to Mr. Sentongo and Mr. Okalanyi (Chemistry Laboratory, School of Food Science, Nutrition and Bio-Engineering, Makerere University), Mr. Musazi (RidaCone), Mr. Kakumba (Beka Ice-cream) and Miss Harriet Namawejje for their technical assistance.

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