Characterisation of the Physico-chemical Properties of Selected White Sorghum Grain and Flours for the Production of Ice Cream Cones

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Abstract: Six white sorghum varieties (MUC007/11, MUC007/27, MUC007/193, MUC007/80, MUC007/171, MUC007/174) available in Uganda were evaluated for their suitability as alternate materials for the production of ice cream cones. Physico- chemical properties of the sorghums were determined and correlated to the properties of the ice cream cones produced from them. Results from this study showed that the swelling power and pasting properties of the flours determined by amylose/amlopectin ratio and amylose content as well as the presence of lipids, dietary fibre, tannins and minerals. The break down viscosity (r=-0.825), the final viscosity(r=-0.834) and amylose/amylopectin ratio (r=-0.782) attained had the highest correlation with the ice cream permeability and weight while hardness of the cone correlated with dietary fibre content (r=0.576), tannin content(r=0.75) and protein (r=-0.458). Hardness showed highest correlation with setback (r=-0.859) and final viscosity(r=-0.703) while texture showed highest correlation with hardness (r=-0.662) and set back(r=0.778). The cone appearance correlated highest with particle size (r=0.696) and dietary fibre (r=-0.693). An amylose content of about 28% and lipid content of about 3% with endosperm texture rated as 3 (scale ;1-corneous and 5-floury), 0.1% Tannins, 1.7% minerals and dietary fibre of 5%, in the *epuripur* variety produced the best sorghum ice cream cone.

Keywords: Ice cream cones, Physico-chemical properties, Sorghum.

1. INTRODUCTION

Sorghum (*Sorghum Bicolor (L) Moench*), is an important cereal grain in the developing countries due to its drought resistance and relatively low input costs [1, 2]. In Uganda sorghum production is well established and has been practiced across communities for centuries. It is consumed predominantly as a primary commodity with little value addition but researchers are working on increasing production of sorghum as well as the value chains that increase its utilization [3, 4]. Currently, more knowledge is being developed on the properties of sorghum and the effects sorghum has on food products which has led to the development of higher quality products as well as innovation using experimental research [1]. As such, sorghum based cones have been developed from *epuripur* white sorghum variety as an alternative to wheat [4]. According to Serna-Saldivar and Rooney (1995), Gomez (1993) and Munck *et al.* (1982) [5-7], it is generally accepted that the physical properties of sorghum grain influence the sensory attributes of sorghum products in various ways. Furthermore it has been established that sorghum varieties differ substantially in their physical and chemical characteristics and therefore will produce products of varied qualities [8]. In particular the suitability for baking of these sorghums is determined by the quality of the milled flour which is in turn determined by grain colour, endosperm texture, grain hardness, grain density (test weight), absence of tannins and grain size uniformity [9].

This research therefore aimed at characterizing white sorghum varieties and establishing their potential as alternative material for the production of ice cream cones. The physico-chemical properties of sorghum varieties under study were established as well as and their behavior during cone production. This information could be used in assisting sorghum breeders and those adding value to sorghum, in producing products of specific sensory characteristics that are well accepted by consumers.

2. MATERIALS AND METHODS

2.1. Sample Selection

From a survey in Uganda under a World Bank Project to unleash the potential of maize and sorghum, carried out by the Department of Crop Science Makerere University, sorghum varieties coded as MUC007/193, MUC007/171, MUC007/27, MUC007/80, MUC007/11 and MUC007/174 were identified from five different districts and multiplied at Makerere University Agricultural Research Institute, Kabanyolo (MUARIK). Locally MUCOO7/193 is known as *Awera*, MUC007/171 as *Oryematera* and the others were unknown. *Epuripur* sorghum grain used as the control was obtained from Serere Agricultural and Animal Research Institute (SAARI), Serere district, Uganda. The grains were

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ground into fine flour using a Wonder Mill (International model, Wonder Mill, Korea).

2.2. Determination of the Physical Properties of the Selected Sorghum Grains

Physical properties of the grains were determined in completely randomized experimental design. The grain size was determined with a vernier caliper following the method described by Mohsenin,(1986) [10]. Grain size was determined in triplicate for ten grains for each of the seven grain varieties as well as the control (*epuripur* variety). The kernels were described as oblate spheroid [10] and volume in cm^3 is determined using equation (1),

$$V = 4/3\, \pi\, a^2 b \quad (1)$$

Where a and b are the length and width of the maximum projected area respectively.

The kernel weight was measured by taking the weight of 100 sorghum kernels in triplicate and density as the ratio of mass to volume. To determine the endosperm texture, longitudinal sections of half cuts of 20 random samples of each grain variety were examined in triplicate. Endosperm texture was rated on a scale of 1-5 (1-corneous, 2, 3, 4-intermediate, 5-floury) according to Rooney and Miller, (1982) [8].

The proximate composition of the grains specifically moisture content, lipid, ash, fibre, carbohydrate, protein, tannin contents of flour were determined according to AOAC (2000) [11] for the selected seven sorghum varieties as well as the control, in triplicates. The total starch was determined in triplicate using the method by Dubois *et al*, 1956 [12]. The amylopectin/amylose ratio for the eight samples was determined in triplicate using the method according to Mahmood *et al.,* 2007 [13] with modifications. The absorbance of resultant solution was read at 620nm and 535nm, using a scanning spectrophotometer Genesys 10UV (Thermo Nicolet, PT. BERCA, Indonesia). The amylose/ amylopectin ratio was calculated using the formula below;

$$A620/ A535 = \text{amylopectin / Amylose ratio} \quad (2)$$

2.3. Determination of the Physical Properties of the Flours of the Selected Sorghum Grains

The mean particle size and particle size distribution of the flours were determined in a completely randomized experimental design. Particle size distribution of the flours was determined using 150µm, 200µm, 250µm, 300µm, 425µm, 500µm and 600µm US standard sieves. Results were plotted to show the particle size distribution as percentage retained above each sieve. The mean particle size (d) was calculated using equation 2 [14].

$$d = \frac{1}{\sum \left(\frac{\omega}{x} \right)} \quad (3)$$

Where ω = mass fraction and x = Average aperture size

The colour of the different sorghum flours was determined using a Lovibond Tintometer Model E (Tintometer Limited, Lovibond House, Solstice Park, Amesbury, UK). The sorghum flour was compared to the reference red, yellow, blue and neutral (white) colours, using a viewing tube and adjusting the knobs until the colour matches were found.

Swelling Power of the flours of the different varieties was determined according to a method described by Van Hung *et al.* (2007) [15], with slight modifications. Samples of 1g of flour (W_1) were measured into a test tube, each mixed with 5 ml of distilled water and heated in a water bath at 40, 50, 60, 70, 80, and 90°C for 30 minutes. The heated samples were cooled to room temperature in a cold water bath and then centrifuged at 3000 rpm using for 15 minutes. The supernatant was carefully removed and the weight of the sediment (W_2) was determined.

$$Swelling\ Power = \frac{W_2 - W_1}{W_1} \quad (4)$$

Pasting properties of flour for each of the eight samples were determined in triplicate. Measurement was done using a Rapid Visco Analyzer, RVA-4 (New Scientific Pty. Ltd: Warrie wood, Australia). The standard 1 heating profile was used. [16]

2.4. Determination of the Functional Properties of the Sorghum Cones

Cones from the different sorghum flours were baked using a formulation according to Kigozi *et al*. 2011[4] in a Cone Machine (Model DST-12 Ice cream Egg tray Machine, (Wuhan Saite Machinery Co.,Ltd, Wuhan, China) at 150°C for the lower mould and 200°C for the upper mould. Hardness of the cones was determined using a penetrometer AFG series (T.W.L Force Systems, Stubbington, UK). A probe of 2.28N was dropped onto a cone, the deflection on the equipment scale showed the extent of penetration. Hardness was tabulated as the reciprocal of the resulting penetration. Ice cream permeability was measured as the time taken for ice cream to permeate through a given cone. Ice cream cones were set on test tube racks in triplicate and loaded with soft serve ice cream from a commercial ice cream parlour. The time taken for the ice cream to permeate to the outside of the cone was measured in minutes and recorded as the ice cream permeability of the cone.

2.5. Statistical Analysis

Data was analyzed using SPSS version 15 using a general linear model at a 5% level of significance. Means and standard deviations were recorded for the different properties. Differences between the means of the properties were determined using the method of least significant difference (LSD) in SPSS at a 5 % level of significance. The properties of the grains and cones were also correlated at 5 % level of significance.

3. RESULTS AND DISCUSSION

3.1. Physical Properties of the Sorghum Grains

The mean values of grain size, volume, endosperm texture, pericarp thickness and mean particle size of the sorghum grains are presented in Table **1**. These values compared relatively well with those given by Ferholz (2006); Rooney and Miller (1982); FAO (1995); and Waniska (2000)

Table 1. Physical Properties of the Selected Sorghum Grains

Sorghum Variety	Grain Size Axis a Axis b Axis c (length) (width) (Thickness)			Volume V= 4/3 π a^2b (cm^3)	Kernel Weight (g)	Density g/cm3	Endosperm Texture*
	(cm)	(cm)	(cm)				
MUC007/171	0.370	0.310	0.204	0.022	0.0185	0.832	1 (corneous)
MUC007/27	0.460	0.380	0.213	0.042	0.0178	0.423	5 (floury)
MUC007/80	0.450	0.400	0.231	0.042	0.0200	0.476	5 (floury)
MUC007/11	0.450	0.350	0.206	0.037	0.0183	0.494	4 (Intermediate floury)
MUC007/174	0.380	0.300	0.205	0.023	0.0174	0.767	2 (Intermediate corneous)
MUC007/193	0.430	0.350	0.190	0.034	0.0182	0.668	4 (Intermediate floury)
Epuripur	0.480	0.410	0.240	0.050	0.0334	0.676	3 (Intermediate)

*Endosperm texture is derived from Fig. (**1**).

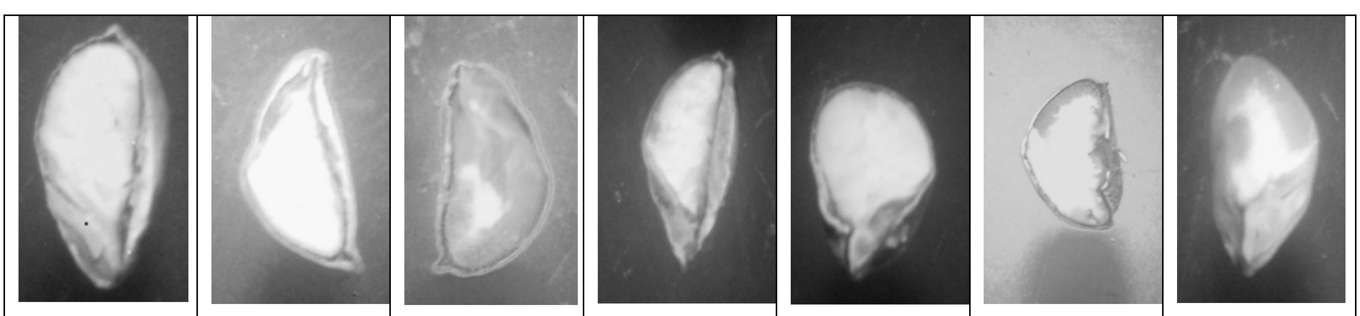
[1, 8, 17, 18,], as they describe the structure of the sorghum kernel.

Longitudinal Sections of the grains are shown in Fig. (**1**). In corneous endosperm, the structure gives a translucent appearance which appears as dark shades in Fig. (**1**) while that of floury has an opaque or chalky appearance which appears as brighter white shades [5, 19]. The opaque appearance of the soft endosperm is caused by air spaces diffracting light and the hard endosperm is translucent because it has no air spaces [8]. On a scale of 1-5 with 1 representing corneous or completely hard and 5 floury or completely soft, MCU007/-171 was rated as 1, MCU007/174 was rated 2, *epuripur* was rated 3, MCU007/11 & MCU007/193 were rated 4, and MCU007/27& MCU007/80 were rated as 5. MCU007/80 were rated as 5.

The corneous variety had the highest density at 0.832 g/cm^3, the intermediate varieties had densities ranging from 0.676-0.494 g/cm^3 and the floury had the least values of 0.476 g/cm^3 and below. The endosperm texture correlated highly significantly with the grain density (r = 0.935); the more corneous the variety, the denser was its structure and the more floury varieties were more lightly packed. This is because the corneous endosperm contains a protein matrix which exists in continuous interface with starch granules forming a compact structure while the floury endosperm also contains protein matrix and starch granules but has a comparatively loose structure with air voids. Serna-Saldivar and Rooney (1995), Rooney and Miller (1982) & Kirleis and Crosby (1982) [5, 8, 20], also found that endosperm texture (relative proportion of hard to soft scored on a 1 to 5 scale where 1 represented completely hard) was negatively correlated with hardness, test weight, and kernel density.

The results are shown in the Figs. (**2** and **3**) show the mean particle size and distribution of the flours from the seven sorghum varieties.

The particle size correlated with endosperm texture (r =-0.639) and grain density (r = 0.585) as also reported by Kirleis and Crosby (1982) [20]. Corneous sorghum grains with higher grain density yielded flours with larger mean particle size of resulting flour samples which agrees with findings by De Francisco *et al.* (1982)[21], that hard endosperm seeds were seen to produce flours with large particle size after milling. It was also noted that the larger seeds gave larger mean particle size of the flours for grains of the same densities and endosperm texture. The fineness of the flour is therefore dependent on the endosperm texture and the size of the grain kernels which agrees with the findings of Eggum *et al.* (1982)[22] who reported that milling characteristics of sorghum kernels are determined by endosperm texture, size and shape of the kernels. Kirleis and Crosby (1982) [20] has also been able to predict milling characteristics with endosperm texture, kernel density and particle size index, plus the kernel parameters (thousand kernel weight and kernel volume) using linear equations.



MCU007/11	MCU007/27	MCU007/171	MCU007/193	MCU007/80	MCU007/174	*Epuripur*

Fig. (1). Longitudinal sections of the sorghum grains under study of seven varieties.

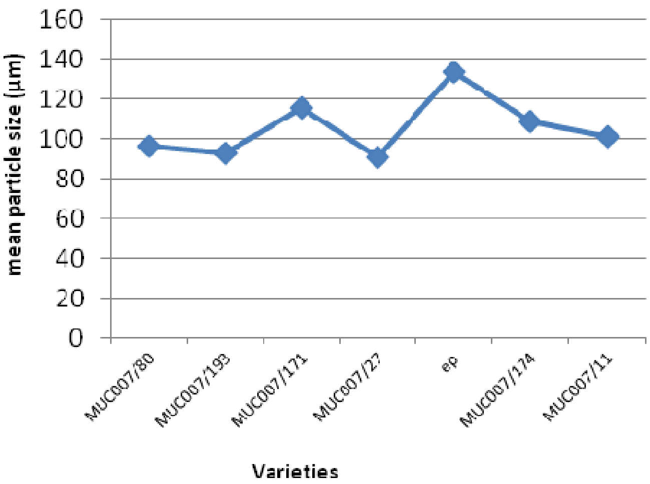


Fig. (2). Mean Particle size of sorghum flours.

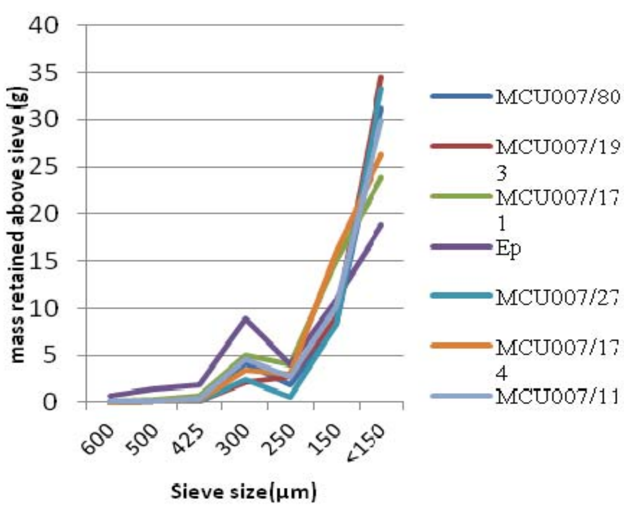


Fig. (3). Particle size distribution of sorghum flours.

3.2. Chemical Properties of the Grains

Table **2** summarizes the chemical composition of the selected sorghum varieties. Results were in agreement with those of Fernholz (2006); Kebakile (2008); FAO (1995); Waniska (2000) and Desikacher (1982); and [1,9,17, 18, 23].

In determining the colour of the sorghum flours using a Lovibond Tintometer, even when the kernels appeared white, generally the flours of these selected varieties had a cream to pale red colour corresponding to the tints of red and yellow as measured on the Lovibond scales. Varieties MCU007/174 and MCU007/171 had the highest red colour (1 and 1.1) and appeared as a pale red flour due to the shade of yellow (0.8, 0.8). Varieties MCU007/80, MCU007/193, MCU007/11 and MCU007/27 (with 0.9, 0.8,0.9 and 0.6 red values respectively) appeared paler than MCU007/171 and MCU007/174 due to the lower red value while MCU007/11 and MCU007/27and appeared paler than MCU007/80 and MCU007/193 (0.3,0.5 yellow values respectively) due to the higher shade of yellow. *Epuripur* variety appeared more creamy as compared to the other varieties due to it lower values or red and yellow and was seen to be the only true white variety with barely any tannins. These results correlated well with the Tannin content as shown in the Table **2**; higher tannin values corresponded to more coloured sorghum flour.

Correlations between the physical and the chemical properties showed that the soft endosperm texture correlated significantly highest (negatively) with amylose content (r = -0.965) and amylose/amylopectin ratio (r =-0.881) and positively with lipid content (r = 0.756). This is consistent with the findings by Beta *et al*. 2001 and Cagampang and Kirelis (1984) [24, 25] who established that sorghum amylose content correlated positively with hard endosperm texture. Ash (r = -0.661) and Tannin (r = 0.544) and also showed correlation with endosperm texture. This could possibly be because tannins bond with proteins [26] that play a role in endosperm structure. According to Munck *et al.* (1982) [7] the yield of fat is positively correlated with soft endosperm while the yield of ash depends on percent soft seeds and hardness of the grain kernel. Grain density also correlated highly with amylose content (r=-0.898) and lipid content(r=0.8). Kirelis and Crosby (1982)[20], also found that the percent kafirin of total protein shows low correlation coefficients with endosperm texture and kernel density which agrees with results of the current study (r=0.11 and r=-0.44 respectively). Particle size i.e increase in coarseness of flour was seen to correlate negatively with the amylose content (r=-0.80), dietary fibre (r=-0.655), ash (r=-0.853) amylose/amylopectin ratio

Table 2. Chemical Composition of the Selected Sorghum Grains

Sorghum Variety	Ash µ(SD) µ(SD)	Lipid µ(SD)	Dietary Fiber µ(SD)	Protein µ(SD)	Starch Content µ(SD)	Amylose/ Amylopectin ratio µ(SD)	Amylose% µ(SD)	Tanin Content (mg CE/g d.b)
MCU007/171	1.98(0.72)^{cd}	3.79(0.05)^{a}	6.31(2.57)^{c}	11.56(0.22)^{a}	53.7(0.3)^{f}	0.55(0.19)^{e}	19.05(0.44)^{d}	7.57(0.0)
MCU007/27	2.25(0.07)^{b}	2.47(0.04)^{f}	10.00(0.25)^{a}	10.69(0.22)^{b}	74.6(0.5)^{b}	0.91(0.12)^{b}	35.47(0.3)^{a}	2.36(0.0)
MCU007/80	2.32(0.02)^{ab}	3.04(0.08)^{e}	6.39(0.19)^{c}	11.55(0.22)^{a}	76.2(1.6)^{a}	0.91(0.01)^{b}	36.23(0.93)^{a}	0.42(0.0)
MCU007/11	2.16(0.07)^{b}	3.43(0.03)^{d}	9.89(0.247)^{a}	11.33(0.0)^{a}	62.2(0.7)^{d}	1.01(0.02)^{a}	31.29(0.21)^{b}	5.61(0.0)
MCU007/174	1.93(0.07)^{d}	3.69(0.03)^{b}	9.43(0.282)^{a}	10.90(0.00)^{b}	58.6(0.6)^{e}	0.67 (0.00)^{d}	23.49(024)^{c}	10.75(0.0)
MCU007/193	2.04(0.05)^{c}	3.55(0.05)^{c}	8.33(0.23)^{b}	10.06(0.45)^{c}	68.4(0.7)^{c}	0.92(0.013)^{b}	32.78(0.52)^{b}	9.11(0.0)
Epuripur	1.70(0.0)^{e}	3.10(0.3)^{e}	5.09(0.83)^{d}	10.6(0.00)^{b}	68.5(0.0)^{c}	0.72(0.00)^{c}	28.63(0.00)^{c}	0.10(0.00)

1. Values followed by the same subscript in the same column are not significantly different at P≤ 0.05.

(r=-0.65) and grain density (r=0.585). This implies that finer flours can be achieved with varieties with higher amylose content as well as lower dietary fibre.

3.3. Swelling Power

Swelling power (SP) of the different varieties at temperatures of 40, 50, 60, 70, 80, 90 °C was determined and results are shown in the Fig. (**4**). Three different trends (Fig. **4**) were observed which were noticeably according to the three different categories of endosperm textures among the sorghum varieties; floury with endosperm texture rated as 5, intermediate with endosperm texture rated as 2, 3 or 4 and corneous with endosperm texture rated as 1.

Fig. **4**(**A**) shows that minimal swelling is achieved between 40-64°C but this begins to change as is depicted by the sharp rise in the swelling power, when the temperature rises beyond their gelatinization temperature (65-75°C.) and sorghums begin to swell. This is because unmodified starch granules are generally insoluble in water below about 50°C but when heated in water beyond a critical temperature, the granules absorb a large amount of water and swell to many times their original size [16].

The gelatinization temperature provides an indication of the minimum temperature required to cook a given sample which can have implications for the stability of other components in a formula and indicate energy costs [16]. For the floury varieties, this temperature occurred at about 65 °C and rose gently until 90 °C. For the intermediate and corneous-varieties it occured at about 75 °C and that for the corneous varieties is much steeper and actually got to a peak at about 80 °C. According to Newport Scientific, (2007) the peak shown by the corneous variety (MCU007/171) occurs at the equilibrium point between swelling and polymer leaching and the rupture and alignment of amylose polymers. It is indicative of the water binding capacity of the starch. This implies that the corneous variety MCU007/171 has a high water binding capacity and was able to take in water to reach the peak of gelatinization unlike the other varieties. The least binding capacity was shown with the floury varieties which needed more water for increased swelling. For the intermediate varieties, MCU007/193 and *Epuripur* seem exhibit higher swelling capacity at higher temperatures than others. These two varieties take longer to peak off, which implies that higher swelling capabilities. The SP at 40 and 50 °C for all the varieties (Table **3**) correlated highly significantly with

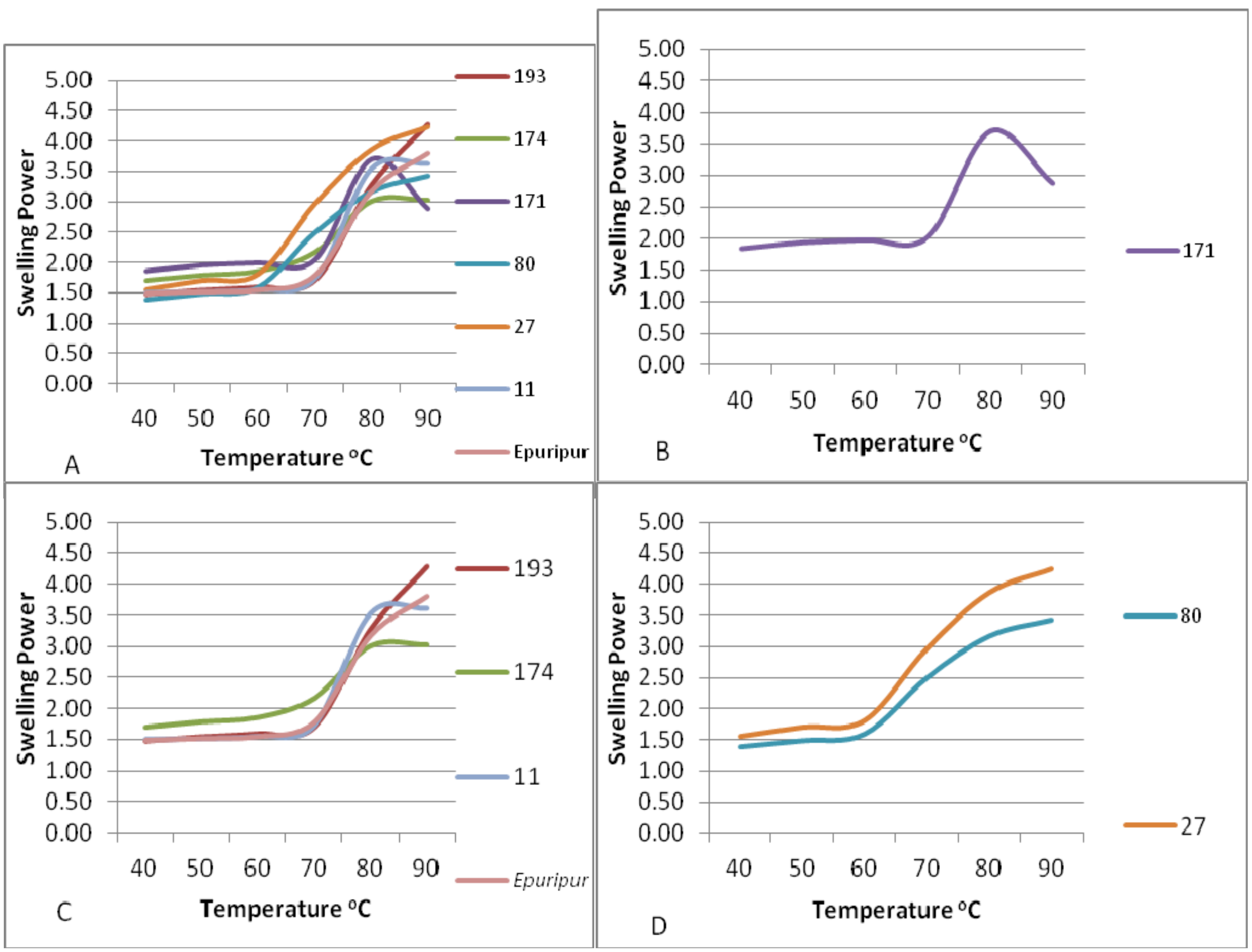


Fig. (4). (**A**) Swelling Power of the selected sorghum varieties (**B**)Swelling Power of corneous variety (**C**) swelling Power of Intermediate varieties (**D**) Swelling Power of floury varieties.

each other, implying that the factors determining SP at these temperatures were similar. As temperatures rose to 70°C and 80°C there was no correlation at this temperature with 40°C and 50°C but barely with 60°C. This depicts the swelling and rupturing and leaching of starch polymers causing a change in structure. At 90°C it was observed that there was correlation of SP with that at the lower temperatures (40, 50, 60°C,) depicting the restructuring of the starch polymers.

A correlation of SP at different temperatures with physical and chemical properties of the grains showed that SP at 40, 50 and 60°C correlated greatest with the amylose/amylopectin ratio. The higher the amount of amylose content compared to the amylopectin content in the starch in the grains, the lower was the SP exhibited. Many important physicochemical, thermal, and rheological properties of starch are influenced by the ratio of amylose and amylopectin, the two major polymers in the starch granule, and by the structure of amylopectin [2]. This arises from the fact that swelling occurs as the structure of the starch breaks down and therefore it will be dependent on the rate at which the amylose and amylopectin breakdown. The amylose double helixes occur over a length of 40-80 residues as compared to the amylopectin double helixes that occur over a length 15-20 residues [27] and therefore a starch with more amylose is harder to breakdown, so swelling will be initiated at a slower pace. This is illustrated in Fig. (**4**); the variety with the lowest ratio (variety 171) had the highest SP at the start and and variety 11 the lowest. As the temperature increases further, the starch granules continue to swell and eventually rupture and the relatively soluble amylose leaches out into solution. At 40°C the presence of lipids and minerals also significantly positively and negatively respectively, affected the SP (Table **4**).

At 70 °C, as noticed earlier there was a change in factors affecting SP because at this temperature, SP correlated most significantly and negatively with lipid content and significantly positively with amylose content. This implies that lipids in the starch inhibited the water intake as swelling progressed while the amylose leaching into solution positively affected the water intake. For these reasons, the floury varieties with less lipid content and high amylose content exhibited a sharp rise in SP at a lower temperature (60 °C) than the intermediate and corneous (70 °C). At 90 °C the SP correlated positively and highly significantly with the amylose content and significantly negatively by the lipids in the sorghum grains. This could be due to the formation of amylose-lipid complexes as the starch restructures. Amylose inhibits swelling of starch granules by forming complexes with lipid, which results in a lower peak viscosity at a higher pasting temperature [2] as shown by Variety MCU007/27 that attains a swelling power of 3 at a temperature of 75 °C for floury variety MCU007/27 as compared to 80 °C for varieties floury MCU007/80. The practical relevance of this observation is that use of floury variety MCU007/27 can lead to saving in energy equivalent to a temperature rise of 5°C. The floury variety with high amylose and low lipid content, therefore attained the highest SP.

Hamaker and Bugusu (2003) [28] also found that overall, sorghum proteins are not considered to have a large role in creating textures in foods because of their encapsulation in rigid protein bodies that persist through most food preparations. But at higher temperatures during cooking, these pro-

Table 3. Correlations between Swelling Power at Different Temperatures($P \leq 0.05$)

	SP 40°C	SP 50°C	SP 60°C	SP 70°C	SP 80°C	SP 90°C
SP 40°C	1					
SP 50°C	0.945**	1				
SP 60°C	0.852**	0.935**	1			
SP 70°C	-	-	0.448*	1		
SP 80°C	-	-	-	-	1	
SP 90°C	-0.586	-0.585	-0.497*	-	-	1

Table 4. Significant Correlations between Swelling Power and Properties of the Sorghum Grains($P \leq 0.05$)

	Amylose	Amylose Amylopectin Ratio	Particle Size	Ash	Protein	Lipid	Tannin
SP 40°C	-0.723**	-0.769**		-0.531**		0.506*	
SP 50°C	-0.625**	-0.754**		-0.415*			
SP 60°C	-	-0.649**					
SP 70°C	0.456*		-0.444*	0.572**		-0.708**	-0.445**
SP80°C							-0.368*
SP 90°C	0.686**	-0.636	-0.586*		-0.481	-0.477*	

teins have been seen to form large extended web-like protein structures due to disulfide-mediated polymerization [28]. This seems to be the case at SP 90 °C were proteins suddenly show correlation with SP (Table **4**). Generally SP was correlated highest with amylose/amlopectin ratio and therefore amylose content as well as lipid content. These factors are therefore expected to play a leading role during cone production. To a lesser extent effects due to ash content, tannins and particle size were also noted.

3.4. Pasting Properties

The behavior of the sorghum varieties upon heating and cooling (pasting properties) was further studied using a Rapid Visco Analyser, RVA-4 and tabulated in Table **5**. The breakdown was highest for variety MCU007/27 and lowest for variety MCU007/174 which was very low compared to the other varieties. This is because variety MCU007/174 had the highest lipid content thus forming more amylose-lipid complexes which agrees with findings by Yijun *et al* (2008) [2] that amylose-lipid complexes increase the rigidity of granules by limiting swelling resulting in smaller breakdown in starches. The set back and final viscosity were highest for the floury varieties which agrees with findings by Yijun *et al* (2008) [2] that higher amylose starches showed a higher setback than low amylose starch, which reflects the three-dimensional structure formed by amylose. The pasting properties were correlated to the physical properties, proximate anlaysis and SP of the sorhgum varieties and the results are in Table **6**. The pasting temperature and peak time correlated highly significantly with the SP at 40, 50 and 60 °C while SP at 80 °C and 90 °C at which temperatures break

Table 5. Pasting Properties for Selected White Sorghum Varieties

	Peak Viscosity (cP) μ(SD)	Trough Viscosity (cP) μ(SD)	Breakdown Viscosity (cP) μ(SD)	Final Viscosity (cP) μ(SD)	Setback Viscosity (cP) μ(SD)	Peak Time (cP) μ(SD)	Pasting Temp (cP) μ(SD)
171	2199(35.9)^{d}	1792(20)^{c}	416(19.5)^{d}	3925(22)^{b}	2030(105.5)^{c}	5.67(0.07)^{c}	75.13(0.03)^{f}
27	2679(1.53)^{a}	1961(18)^{a}	715(14.3)^{a}	3972(22.5)^{b}	2011(40.5)^{d}	5.66(0.15)^{c}	86.38(0.13)^{e}
80	2102(8.5)^{e}	1667(2)^{d}	434(6.5)^{d}	4172(2.5$^{)a}$	2505(4.5)^{a}	6.0(0.65)^{a}	88.75(0.25)^{d}
11	2420(23)^{c}	1936(17)^{a}	484(6.0)^{c}	3798(1.0)^{c}	1862(16$^{)e}$	6.13(0.0)^{a}	90.55(0.06)^{b}
174	1331(16.5)^{g}	1249(17)^{e}	82(0.0)^{e}	2495(69)^{f}	1245(52.5)^{h}	5.77(0.04)^{bc}	90.6(0.0)^{b}
193	2388(20)^{c}	1874(37)^{b}	496(1.0$^{)c}$	3475(14.5)^{d}	1660(6.5)^{f}	5.84(0.102)^{b}	89.8(0.104)^{c}
Epuripur	1652(1.52)^{f}	1142(9.5)^{f}	510(10.8)^{bc}	3484(2.0)^{d}	2342(11)^{b}	5.57(0.04)^{d}	84.1(0.0)^{e}

1. Values in parenthesis ( ) are the standard deviation of the mean (μ)

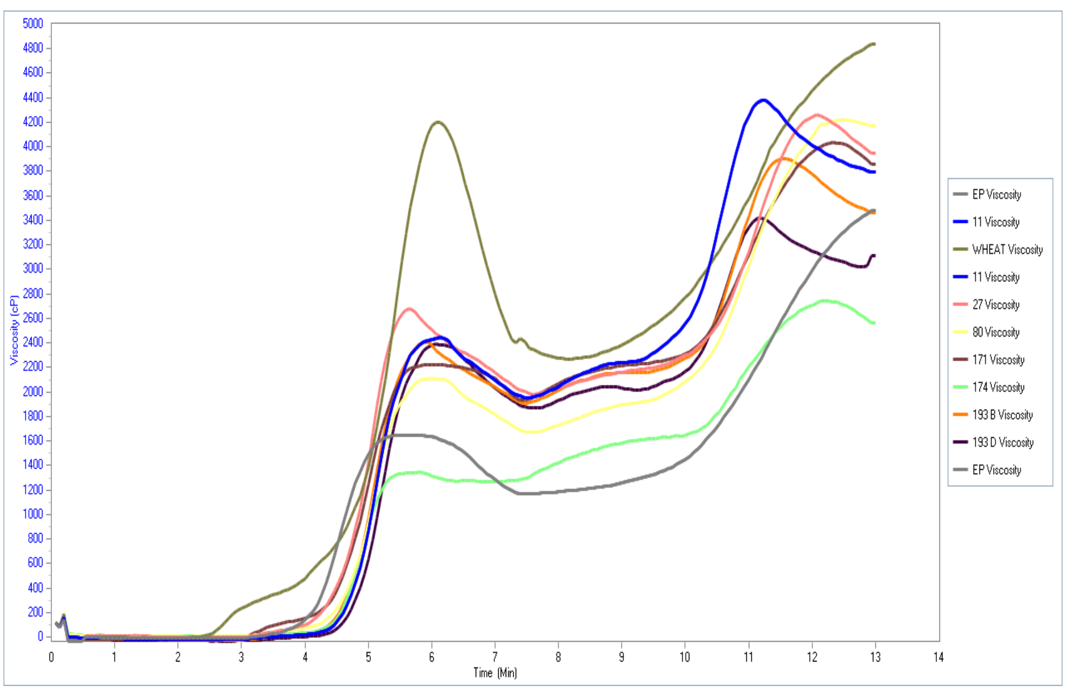


Fig. (5). Graph showing pasting properties of selected white sorghum varieties.

down of starch structures is happening, correlated with peak viscosity, trough viscosity, breakdown viscosity and final viscosity, implying a consistency in results. As in the case with SP, pasting properties (pasting temperature, peak viscosity, peak time, break down, trough viscosity, set back, final viscosity) correlated most highly significantly with amylose and amylose/ amylopectin ratio. This is because amylose content strongly affects starch gelatinization and retrogradation [29, 30] and paste viscosity [31, 32]. The fine structure of amylopectin (chain-length distribution) also was found to influence starch gelatinization and retrogradation properties [33, 34]. The effect of lipids and tannins was very significant during break down, final viscosity. The effect due to tannin may be because tannins bind to proteins in the sorghum [26]. Dietary fibre was also seen to affect the pasting viscosity,trough viscosity and set back. In their study, Sasaki *et al* (2000) [35] also found that amylose content correlated highly with set back and final viscosity but our results showed significant correlation with final viscosity and not setback. Ash content which is an indicator for mineral content, was seen to affect peak viscosity, trough viscosity, break down, final viscosity and set back. A similar effect was also noticed at SP 40, 50 and 70 ^{o}C. Set back was correlated to starch content which agrees with Newport Scientific, (2007) [16], that set back involves the retrogradation and re-ordering of starch molecules. The final viscosity is the most commonly used parameterto define a particular samples quality [16] and it was seen to be affected by amylose, lipid, tannin and ash content.

3.5. Ice cream Cone Characteristics

Ice cream cones were baked from the sorghum varieites (Fig. **6**) and their weight, hardness , ice cream, permeability and sensory evaluation are tabulated in Tables **7** and **8**. The

Table 6. Correlations Between Pasting Properties and Properties of Selected White Sorghum Varieties (P≤0.05)

	Peak Viscosity	Trough Viscosity	Breakdown Viscosity	Final Viscosity	Setback	Peak Time	Pasting Temp
Particle size	-0.638**	-0.743**				-0.52**	-0.49*
Starch			0.529*		0.497*		0.434*
Amylose/amylopectin ratio	0.583**	0.536**	0.478*			0.65**	0.701**
Amylose	0.574**	0.516**	0.482*	0.447*		0.53**	0.623**
Lipid			-0.711**	-0.457*	-0.485*		
Dietary fibre		0.462**			0.665**		0.551**
Tannin			-0.604*	-0.618**	-0.886**		
Ash	0.616**	0.717**		0.558*		0.62**	
SP 40						-0.68**	-0.69**
SP 50						-0.45**	-0.63**
SP 60							-0.57**
SP 80	0.781**	0.731*	0.666**	0.596**			-0.458*
SP 90^{o}C	0.444*		0.496*				0.444*

Fig. (6). Ice cream cones form different varieties.

Table 7. Cone Characteristics of the Selected Sorghum Varietes

Variety	Weight (g) μ(SD)	Hardness (1/penetration(mm)) (μ(SD))	Ice cream permeability (mins) μ(SD
171	15.53(0.09)[b]	1.98(0.27) [b]	28.02(1.24)[b]
27	13.70(0.53)[d]	2.17(0.29) [b]	12.75(0.40) [d]
80	13.16(0.03)[d]	1.22(0.18)[c]	11.88(0.10) [d]
11	13.11(0.09)[d]	1.36(0.33)[c]	12.77(0.36)[d]
174	16.59(0.55)[a]	3.18(0.62) [a]	40.70(0.00)[a]
193	14.04(1.00)[cd]	2.90(0.52) [a]	20.96(1.47)[c]
Epuripur	14.06(0.53)[)cd]	1.89(0.22)[b]	20.73(1.94)[c]

1. Values followed by the same subscript in the same column are not significantly different at P≤ 0.05.

Table 8. Sensory Evaluation of Sorghum Cones

Variety	Appearance μ	Texture μ(SD) (SD)	Taste μ(SD)	Colour μ(SD)	Overall Acceptability μ(SD)
171	6.98(0.293)[b]	5.65(0.314)[b]	5.5(0.295)[c]	6.73(0.302)[b]	6.25(0.282)[b]
27	6.18(0.293)[bc]	5.90(0.314)[b]	5.83(0.295)[c]	5.83(0.302)[bc]	5.85(0.282)[b]
80	5.73(0.293)[bc]	5.96(0.313)[b]	5.65(0.295)[c]	5.60(0.302)[c]	5.85(0.282)[b]
11	6.33(0.296)[b]	7.03(0.318)[a]	7.80(0.299)[a]	6.49(0.306)[b]	7.39(0.286)[a]
174	5.45(0.293)[c]	6.13(0.314)[ab]	6.05(0.295)[bc]	5.58(0.302)[c]	5.90(0.282)[b]
193	5.89(0.296)[c]	5.54(0.318)[b]	5.44(0.299)[c]	5.36(0.306)[c]	5.15(0.286)[c]
Epuripur	7.83(0.293)[a]	6.93(0.314)[a]	6.85(0.295)[b]	8.00(0.302)[a]	7.30(0.282)[a]

1.Scale for all attributes: Range 9 = "like extremely" to 1 = "dislike extremely "(Ramcharitar 2005).
2. Values followed by the same subscript in the same column are not significantly different at P≤ 0.05.

weight of the cone correlated highly significantly at a 5% level of significance with the ice cream permeability(r=0.936), and can therefore be used to predict each other. They both had highest correlation with the amylose/amylopectin ratio (r=-0.782 and r=-0.766 respectively). This implies that the amylopectin/ amylose ratio of the sorghum flour is the factor that most determines these two properties. A comparison of the cone properties with SP and the pasting properties showed that the break down viscosity(r=-0.825 and r=-0.701) and the final viscosity(r=-0.834 and r=-0.689) attained had the highest correlation with the ice cream permeability and weight and can therefore be used to show the potential of a flour for ice cream cone production. These findings agree with the findings of Berry *et al.,* (1988); Sievert and Pomeranz,(1989); Tester and Morrison, (1990) [36,37,38] that the amylose/amylopectin ratio is a property of cereal starches that affects the end product by varying gelatinization, solubility, resistant starch formation, and textural characteristics.

Hardness of the cone on the other hand showed some correlation with dietary fibre content (r=0.576), tannin content(r=0.75) and protein (r=-0.458). This implies that the amount of dietary fibre, tannins and protein could have an effect of strengthening the cone structure and can be used for structure modification in ice cream cone production. A comparison with SP and pasting properties showed highest correlation with setback (r=-0.859) and final viscosity(r=-0.703) which therefore can be used to predict the ice cream cone hardness that can be achieved with a given sorghum flour.

3.6. Sensory Analysis

Results of the sensory analysis showed that generally cones from the varieties *epuripur* and MCU007/11 were most liked.

Correlation of overall acceptability with texture (r=0.899), taste (r=0.88), colour (r=0.821) and appearance (r=0.702) showed that each of the properties is of high significance in determining the acceptability of the cone. The texture showed some correlation with hardness (r=-0.662) and set back(r=0.778). and therefore could be improved by using a flour that results in the appropriate cone hardness or using additives to increase or decrease the hardness as desired. The set back of the sorghum flour can be used to predict the expected cone texture. The cone appearance correlated highest with particle size(r=0.696) and (r=-0.693) and therefore could improved by increasing the fineness of the flour and by use of flour with lower dietary fibre. Starch particle size can impact processing and end-product quality [1].

The colour of the cones from *epuripur* flour which had no colour pigments where most preferred and which agrees with Waniska (2000)[18]; the colors of sorghum grain and flour play an important role in its acceptance; in general, untainted white sorghums produce the most acceptable colored food products.

4. CONCLUSIONS

Results from this study showed that the swelling power and pasting properties of the flours, as well as ice cream cone weight and ice cream permeability were most significantly affected by amylose/amlopectin ratio and amylose content as well as the presence of lipids, dietary fibre, tannins and minerals. A comparison of the ice cream cone properties with swelling power and the pasting properties showed that the break down viscosity (r=-0.825 and r=-0.701) and the final viscosity(r=-0.834 and r=-0.689) attained had the highest correlation with the ice cream permeability and weight and can therefore be used to show the potential of a flour for ice cream cone production. Hardness of the cone on the other hand showed some correlation to dietary fibre content (r=0.576), tannin content(r=0.75) and protein (r=-0.458). This implies that the amount of dietary fibre, tannins and protein could have an effect of strengthening the cone structure and can be used for structure modification in ice cream cone production. A comparison with swelling power and pasting properties showed highest correlation with setback (r=-0.859) and final viscosity(r=-0.703) and therefore they can be used to predict the ice cream cone hardness that can be achieved with a given sorghum flour. The texture showed some correlation with hardness (r=-0.662) and set back(r=0.778) and therefore could be improved by using a flour that results in the appropriate cone hardness or using additives to increase or decrease the hardness as desired. The set back of the sorghum flour can be used to predict the expected cone texture. The cone appearance correlated highest with particle size (r=0.696) and dietary fibre (r=-0.693) and therefore could be improved by increasing the fineness of the flour and by use of flour with lower dietary fibre. An amylose content of about 28% and lipid content of about 3% with endosperm texture rated as 3 (scale ;1-corneous and 5-floury), 0.1% Tannins, 1.7% minerals and dietary fibre of 5%, in the *epuripur* variety produced the best sorghum cone.

CONFLICT OF INTEREST

The author(s) confirm that this article content has no conflicts of interest.

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NOMENCLATURE AND ACRONYMS

%	=	Percentage
^{0}C	=	Degree Centigrade
g	=	gram
r	=	correlation coefficient
π	=	22/7
a	=	Length of maximum projected area
b	=	Width of maximum projected area
AOAC	=	AOAC: Association of Official Analytical Chemists
ml	=	milliliter
M	=	Molar
nm	=	nanometers
UV	=	Ultra violet
A	=	area
µm	=	micrometer
d	=	mean particle diameter
ω	=	mass fraction
x	=	Average sieve aperture
∑	=	summation
Rpm	=	revolutions per minute
W_2	=	weight of sediment
W_1	=	initial weight of sample
RVA	=	Rapid Visco-Analyser
N	=	Newtons
Cm	=	centimeter
Mg	=	milligramme
FAO	=	Food and Agricultural organization
SP	=	Swelling capacity

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