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Functional properties of weaning food blends from selected sorghum (*Sorghum bicolor* (L.) Moench) varieties and soybean (*Glycine max*)

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Weaning food was produced from the blends of sorghum flour, malted sorghum flour and soybean flour. The physicochemical properties of the formulated weaning food were investigated. Flours from three sorghum varieties (local, improved and hybrid sorghum grains) were, respectively, combined with the sorghum malt and soybean flour at different graded levels. The water holding capacity of the weaning food blends ranged between 1.52 and 3.81 ml/g while the viscosity ranged between 14.32 and 33.61 centipoise at 10% (w/v) flour concentration. The least gelation concentration ranged between 8.02 and 20.21 g/ml. The inclusion of sorghum malt in the blends reduced both water holding capacity and viscosity but increased the least gelation concentration. Almost all the pasting variables, except breakdown viscosity, reduced with the inclusion of sorghum malt in the formulations. The range of values for the pasting factors of the weaning food blends include peak viscosity (130.2-532.1 RVU), trough (73.2-335.3 RVU), breakdown viscosity (28.3-97.4 RVU), final viscosity (160.2-826.2 RVU) and setback viscosity (64.1-516.0 RVU). The weaning food blends that could be regarded as appropriate formulation based on the exhibited physicochemical properties are Samsorg 17-(M10) which contained 63, 10 and 27% of raw sorghum flour (RSF), malted sorghum flour (MSF) and soybean flour (SBF), respectively; and Hybrid-(M5) which contained 66.5, 5 and 28.5% of raw sorghum flour (RSF), malted sorghum flour (MSF) and soybean flour (SBF), respectively. Both blends possessed relative low final viscosity, setback value and pasting temperature.

Key words: Weaning food, malting, functional properties, viscosity, soybean.

INTRODUCTION

The consumption of cereal based food products from maize (*Zea mays*), sorghum (*Sorghum bicolor*), millet (*Pennisetum typhoideum*), rice (*Oryza sativa*), etc is very common and popular worldwide especially in developing

African countries where they constitute a major source of their staple food (Gernah et al., 2011). Due to the prevailing unfavourable economic conditions in most developing countries of the world, Africa and Nigeria in particular where over 40% of the population live below poverty line (Nzeagwu and Nwaejike, 2008), the incidence of protein-energy malnutrition among different age groups particularly children with an estimated 400 million children being reported to be malnourished worldwide is highly prevalent and on the increase on a daily basis (Oji, 1994; Oosthuizen et al., 2006; Agiriga and Iwe, 2009). Weaning of infants is highly critical in the life of children as breast milk feeding (4-6 months), which normally precedes the weaning period, can no longer meet their nutritional requirements (Egounlety, 2002). The nutritional qualities of traditional weaning foods in developing countries, particularly in Nigeria, are low in protein content and also devoid of vital nutrients that are required for normal child growth and development (FAO, 2004).

In developing countries, one of the greatest problems affecting millions of people, particularly children, is lack of adequate protein intake in term of quality and quantity. As cereals are generally low in protein, supplementation of cereals with locally available legume that is high in protein increases protein content of cereal-legume blends. Several traditional fermentations have been upgraded to high technology production systems and this has undoubtedly improved the general well-being of the people as well as the economy (Achi, 2005). For instance, the corn gruel (ogi) is the traditional weaning food of infants in many parts of West Africa countries. 'Ogi', an acid fermented gruel or porridge made from maize *(Zea mays*), sorghum (*Sorghum bicolor*) or millet (*Pennisetum glaucum*) is limited by its low protein content especially amino acids notably lysine and methionine (Inyang and Idoko, 2006).

Studies have shown that corn gruel (ogi) is bulky and devoid of essential nutrients, such as protein and vital micronutrients that is needed for normal child growth and development (Levin et al., 1993; Pinstrup-Andersen et al., 1993; Millward and Jackson, 2004). Efforts have therefore been made to improve on the nutritional quality of the traditional weaning foods and these include the incorporation of protein-rich legumes (Ikujenlola and Fashakin, 2005; Kouakou et al., 2013), fermentation of the cereal component (Amankwah et al., 2009) and incorporation of malt in the weaning foods (Odumodu, 2008). Complementary foods are usually introduced between the ages of six months to three years, this is done with gradual withdrawal of breastfeeding. Infants are able to maintain adequate growth until the age of six months when additional nutrients are required to complement breastfeeding. During this transitional phase, protein-energy malnutrition occurs (Ijarotimi and Ashipa, 2006; Ijaratomi and Ayantokun, 2006). It is therefore required to feed infants with highly nutritious food during this period. The general acceptability of weaning foods by infants is greatly influenced by the functionality of the ingredients used for their production. Indeed, the functionality of a food is the property of the food ingredients apart from its nutritional value, which has a great impact on its utilization (Kinsella, 1976). Functional properties such as gelation, water holding capacity, viscosity and pasting properties are very important for ensuring the appropriateness of the diet to the growing child. The consistency and energy density (energy per unit volume) of the complementary diet coupled with frequency of feeding are also important factors in determining the extent to which an infant can meet his other energy and nutrient requirements (Kikafunda et al., 1997). In the processing of most complementary foods, emphasis is usually on the nutritional quality and quantity of the ingredients rather than their functional properties (Bookwalter et al., 1987).

In many regions of Africa where the climatic conditions are unfavorable for the growth of other crops, sorghum is the major staple food (Kinyua et al., 2016). Due to high cost and unavailability of animal products such as milk, legumes are largely used as alternative sources of high quality protein. Cereals are relatively poor sources of protein but have been reported to supply over 70% of dietary protein in developing countries (Ijarotimi and Ashipa, 2006). Also, maternal and child under nutrition remain pervasive and damaging conditions in low income and middle-income countries (Black et al., 2008).

The cereal crops from which weaning or complementary foods are prepared have been undergoing series of genetic engineering in most developing countries including Nigeria in recent time. The specific areas of focus in these genetic engineering efforts include the development of high-yielding cereal varieties (Manyong et al., 2000); yield stability of the grain (Haussmann et al., 2000; Pixley and Bjarnason, 2002); disease-resistant variety (Hess et al., 1992; Bosque-Perez, 2000); cereal varieties with improved mineral and vitamin content (Ortiz-Monasterio et al., 2007); drought-tolerant variety (Campos et al., 2004); and cereal varieties with minimal anti-nutrients (Raboy et al., 2001). These cereal varieties have been observed to have diverse yield potentials in different ecological zones of a country and therefore their assessment across a country has become a necessary established practice in cereal genetic engineering efforts (Iken and Amusa, 2004). Due to high cost and

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unavailability of animal products such as milk, legumes and cereals are largely used as alternative sources of protein in many region of Africa. However, due to lack of proper processing techniques to increase the nutritional value of the crops, infant malnutrition rates are high. Identification of the best varieties of sorghum in terms of their nutritional value diverse yield potentials in different ecological zones of a country and therefore their assessment across a country has become a necessary established practice in cereal genetic engineering efforts (Iken and Amusa, 2004).

Grown in this region and use of appropriate food processing techniques can be used in developing complementary food and help solve malnutrition. Sorghum is a staple food in many African countries and contains reasonable amount of protein, ash, oil and fibre, however, is deficient in essential amino acid content, particularly with respect to lysine.

Weaning foods have been formulated from ungerminated locally-available cereal grains in Nigeria but no serious effort has been made to systematically use hybrid sorghum as comparable to local and improved sorghum varieties. Generally, energy and nutrients density of weaning food can be increased by such operations as enzyme treatments, pre-cooking and extrusion (Mosha and Svanberg, 1983). This type of weaning food formulation usually possesses increased energy density and reduced viscosity but may be too expensive for the poor households in the societies. An alternative solution to this high energy density and chemically balanced food can be achieved through the addition of malted cereal and complimenting the weaning food with high protein legumes. Sorghum is an important source of vitamin B-complex and some other minerals like phosphorous, magnesium, calcium and iron. The protein quality of sorghum is also very similar to that of maize with lysine as the limiting amino acid but rich in methionine (FAO, 1995). Soybean (*Glycine max*) is an important legume reported to contaimn large amount of protein along with other nutrients (IITA, 1990). The protein is high in lysine but low in methionine (Ogazi et al., 1996; Omueti et al., 2000). Malting has been shown to be one of the most effective and convenient ways for improvement of nutritional value of cereals (Adeyemo et al., 1992; Akpapunam et al., 1996; Gernah et al., 2011); and currently there is a growing interest in the formulation of food products using the combination of composite blends of malted cereals and legumes as a way of improving nutritional quality of the product suitable for children (Agu and Aluya, 2004).

Thus, in this study, weaning foods were formulated from locally-available materials in Nigeria (local, improved and hybrid sorghum grains and soybean) with emphasis on the physicochemical properties of their blends. The objective was to evaluate the functional properties of this weaning food in order to know the appropriateness of the diet for infants.

MATERIALS AND METHODS

Three varieties of sorghum grains were used for this study: local sorghum (*Pelipeli*), improved sorghum (Samsong 17, SK5912) and sorghum hybrid. *Pelipeli* was obtained from the Agricultural Development Programmes (ADP) Agency, Yola, Nigeria. The improved sorghum (Samsong 17, SK5912) was gotten from the Institute of Agricultural Research (IAR), Samaru, Zaria, Nigeria; while the sorghum hybrid was sourced from Lake Gerio Research Farm, River Basin Development Authority (RBDA), Yola, Nigeria. Soybean was also obtained from a local market (Yola town main market).

Malting of sorghum grains

Sorted clean grains of sorghum weighing 1000 g were steeped in water (1:3 w/v, grain: water) for 4 h. The steeped grains were then transferred to a wide container with cotton wool to allow for germination at room temperature (30°C) for 5 days. The washed germinated seeds were dried in the oven at 35°C for a total of about 10 to 12 h. The grains were then cleaned of sprouts and hulls by hand rubbing and winnowing, after which they were dried in a forced-air oven at 50°C to a uniform light brown colour. The dried grains were ground to fine flour and passed through a 0.5 mm sieve (Elemo et al., 2011). The modified procedure of Beta et al. (1995) was used for malting the grains from sorghum varieties involved in this study. One kilogramme of grains from each sorghum variety was, respectively, steeped in water at 30±2°C inside a plastic bowl for 20 h. The water in the bowl was replaced with fresh one at 3-h interval to discourage fermentation. After steeping, the grains were immersed in 2% sodium hypochlorite solution for 10 min and then rinsed five times with excess water. The grains were finally spread on damped jute bags for germination at 30±2°C, 95% RH, for five days in a germinating chamber. The germinated grains were eventually dried in a forced-air oven at 50°C for 24 h. The dried malt was cleaned and the roots and shoots were removed by hand using a corrugated, rubber surface; and then kept in a plastic container for subsequent use.

Production of weaning food blends

Flour was, respectively, produced from each varieties of sorghum grain (local, improved and hybrid), soybean and malted sorghum as depicted in Figure 1. Thereafter, weaning food blends were prepared from the flours using the composite formulation as shown in Table 1. Essentially, the raw sorghum grains were sorted, cleaned and dried to prepare them for milling. They were then milled using a disc mill and sieved by passing through a 425 µm-sieve to produce fine raw sorghum flour (RSF) which was then used for subsequent weaning food formulation. The malted sorghum grains initially obtained were milled to produce malted sorghum flour (MSF), also at 425 µm particle size, which was then stored properly under room temperature (30±2°C) and then used for subsequent formulation of weaning food. The processing of the soybean flour was carried out as described by Gbenyi and Wilcox (2002). Three types of weaning food blend were prepared from each sorghum variety containing 0, 5 and 10% of malted sorghum flour (MSF), respectively; in combination with soybean flour at varying levels. This was guided by the expected energy and nutrient density in the weaning food.

Determination of the functional properties of the blends

Water binding capacity

The water binding capacity (WBC) was determined by the modified

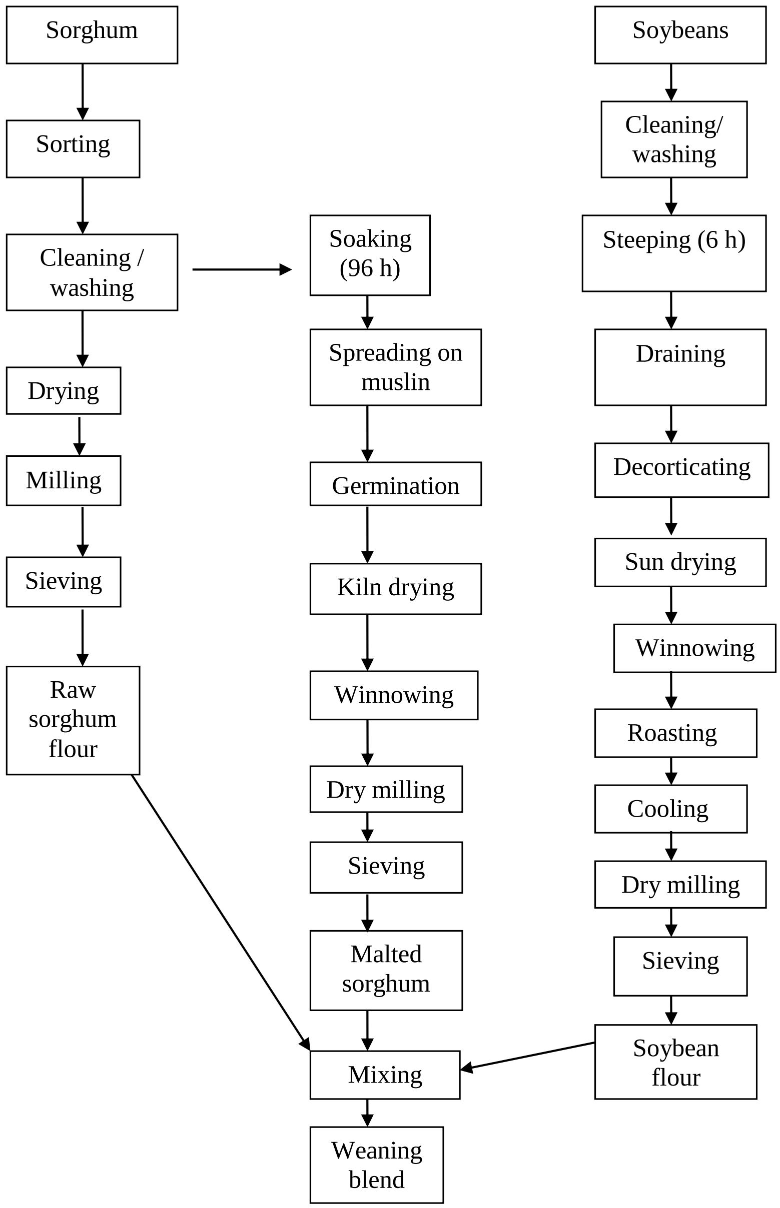

Figure 1. Production of sorghum-soybean weaning food blend.

method of Lin and Humbert (1974). Two grams of the food blend were added to 20 ml of distilled water in a test tube, stirred briefly with a magnetic stirrer and allowed to stand for 1 h at room temperature (30±2°C) before being centrifuged at 2460 rpm. The supernatant water was decanted by inverting the tubes over filter paper placed in a volumetric flask. The sample was allowed to drain for about 35 min and the weight of the bound water was determined by the difference between initial and final weight of sample.

Viscosity

The determination of viscosity of the weaning food blend was carried out using the procedure described by Coffman and Gracia (1977). Viscosity of the blend was assessed using rotational viscometer. The gruel from each blend was first prepared by mixing 10% (w/v) of the flour and water in a beaker which was heated in a boiling water bath to reach a cooking temperature of 95±1°C. The gruel was kept at this cooking temperature for about 15 min with occasional stirring until it was finally cooled down to 40°C and its viscosity measured in centipoise (cP).

Least gelation concentration (LGC)

Least gelation concentration was determined by using the method described by Malleshi and Desikachar (1982). Sample suspensions of 2-20% (w/v) were prepared in test tubes with 5 ml of distilled water, respectively. The suspension was then mixed using vortex mixer for 5 min. The test tubes containing the suspension were heated for 1 h in boiling water followed by rapid cooling under cold running water. The tubes were further cooled at 4°C for 2 h. The least gelation concentration is the concentration at which the sample from the inverted tube did not slip or fall.

Table 1. Composite formulation of weaning food blends from raw sorghum flour (RSF), malted sorghum flour (MSF) and soybean flour (SBF).

Source of weaning food blend	Raw sorghum flour (RSF) (%)	Malted sorghum flour (MSF) (%)	Soybean flour (SBF) (%)
Local sorghum grain:			
Pelipeli- (M0)	70	0	30
Pelipeli- (M5)	66.5	5	28.5
Pelipeli- (M10)	63	10	27
Improved sorghum grain:			
Samsorg 17- (M0)	70	0	30
Samsorg 17- (M5)	66.5	5	28.5
Samsorg 17- (M10)	63	10	27
Hybrid sorghum grain:			
Hybrid- (M0)	70	0	30
Hybrid - (M5)	66.5	5	28.5
Hybrid - (M10)	63	10	27

Pasting properties

Pasting properties of the weaning food blend were carried out using a Rapid Visco-Analyzer (RVA-Series 4, Newport Scientific, Sidney, Australia). A sample of 4.0 g weaning food (14% moisture-basis) was transferred into a canister and approximately 25± 0.1 ml distilled water was added (correction factor was used to compensate for 14% moisture-basis). The slurry was stirred at 160 rpm for 10 s for thorough dispersion and heated to 50°C. The slurry was held at 50°C for up to 1 min followed by heating to 95°C for about 7.3 min and held at 95°C for 5 min, then cooled at the same rate to 50°C. The pasting parameters were obtained automatically and generated from the software attached to the RVA. The parameters were pasting temperature, peak viscosity (the maximum hot paste viscosity), time to peak, breakdown (peak viscosity-holding strength or through), holding strength or trough, setback (final viscosity – holding strength) and final viscosity (viscosity at the end of the test after cooling at 50°C and holding at this temperature).

Statistical analysis

All determinations reported in this study were replicated three times (performed in triplicate). In each case, a mean value and standard deviation were calculated. Analysis of variance (ANOVA) was also performed and separation of the mean values was by Duncan's Multiple Range Test at $p \leq 0.05$. The Statistical Package for Social Scientists (SPSS) software, version 16.0; was used for the analysis.

RESULTS AND DISCUSSION

Water binding capacity, viscosity and least gelation concentration of weaning food blends from sorghum varieties

Water binding capacity (WBC) measures the amount of water absorbed by starch and used as an index of gelatinization. WBC also depends on the availability of hydrophilic groups that bind water molecules on the gel-forming capacity of macromolecules (Onyeka and Dibia, 2002). The results of WBC of the blends are shown in Table 2. There were significant differences ($p \leq 0.05$) observed in the water binding capacities of the blends from sorghum varieties. Inclusion of malted sorghum flour (MSF) in the weaning food blends resulted in a decrease in water binding capacity (WBC). The WBC of Samsorg 17-(M0), *Pelipeli*-(M0) and Hybrid-(M0) were 3.81, 3.51 and 3.31 ml/g, as shown in Table 2. The WBC was also observed to decrease with an increase in the quantity of MSF included. This observation essentially conforms to an earlier observation that the inclusion of malt in a flour blend usually tends to lower its water binding capacity (Onyeka and Dibia, 2002). This has to do with possible enzymatic breakdown of the starchy component in the malt flour which might have led to simple sugar availability. A high WBC reflects high starch content and is also dependent on the availability of hydrophilic groups that bind water molecules and on the gel-forming capacity of the macromolecules (Onyeka and Dibia, 2002).

The viscosity of the weaning food blends is shown in Table 2. The values ranged from 14.32 to 33.61 cP with Hybrid-(M10) and *Pelipeli*-(M0) having the lowest and highest values, respectively. At the temperature (40°C) in which the viscosity of the weaning food blends was measured, it was observed that the viscosity of the blends generally decreased with an increase in the quantity of malt added. The implication of this observation is that the inclusion of malt in the blends tends to cause a decrease in the viscosity. This observed decrease in viscosity could be attributed to an increase in amylolytic activity as a result of the increase in the quantity of malt

Table 2. Water holding capacity, viscosity and least gelation concentration of weaning food blends from sorghum varieties.

Source of weaning food blend	Water binding capacity (ml/g)	Viscosity (cP)	Least gelation concentration (g/ml)
Local sorghum grain:			
Pelipeli- (M0)	3.51±0.32[ab]	33.61±0.05[a]	8.02±0.05[g]
Pelipeli- (M5)	2.52±0.29[c]	29.42±0.03[d]	10.67±0.03[f]
Pelipeli- (M10)	2.14±0.02[cd]	26.31±0.04[e]	16.02±1.04[c]
Improved sorghum grain:			
Samsorg 17- (M0)	3.81±0.48[a]	32.33±0.11[b]	14.11±0.11[d]
Samsorg 17- (M5)	2.32±0.11[cd]	24.42±0.02[f]	16.05±0.02[c]
Samsorg 17- (M10)	2.13±0.21[cd]	11.89±0.03[i]	18.12±0.03[b]
Hybrid sorghum grain:			
Hybrid- (M0)	3.31±0.05[b]	30.04±0.05[c]	12.03±0.05[e]
Hybrid - (M5)	2.01±0.15[d]	23.07±0.09[g]	18.09±0.09[b]
Hybrid - (M10)	1.52±0.07[e]	14.32±0.02[h]	20.21±0.06[a]

Values are mean ± standard deviation of three determinations. Values with different superscripts in a column are significantly different at p ≤ 0.05. M0 = Weaning food blend containing 70, 0 and 30% of raw sorghum flour (RSF), malted sorghum flour (MSF) and soybean flour (SBF), respectively. M5 = Weaning food blend containing 66.5, 5 and 28.5% of raw sorghum flour (RSF), malted sorghum flour (MSF) and soybean flour (SBF), respectively. M10 = Weaning food blend containing 63, 10 and 27% of raw sorghum flour (RSF), malted sorghum flour (MSF) and soybean flour (SBF), respectively.

in the blend. It had earlier been observed that the process of cereal malting normally releases certain enzymes such as α-amylase which is capable of digesting amylose and amylopectin to dextrins and maltose. These low molecular weight carbohydrates contribute to reduced viscosity, have less water-binding capacity and may be more easily digested and absorbed as required by infants (Alvina et al., 1990). Therefore, reduced viscosity is a good indicator for the appropriateness of a weaning food blend for infants. Least gelation capacity (LGC), an index of gelling tendency of bends, is very important with respect to porridges (Onyeka and Dibia, 2002). LGC was taken as a measure of the gelation capacity and the lower the LGC, the better the gelation characteristics of the flour. This demonstrated that *Pelipeli*-(M0) blend would have better gelation characteristic than Hybrid-(M10). The LGC of the weaning food blends ranged between 8.02 and 20.21 g/ml with *Pelipeli*-(M0) and Hybrid-(M10) having the lowest and highest values, respectively, at significant level of $p \leq 0.05$ (Table 2). The blends without the inclusion of malted sorghum flour were observed to have lower LGC than their counterparts with malted sorghum flour inclusion. The LGC was increasing with an increase in the quantity of malted sorghum flour added in each of the sorghum varieties used. The LGC measures the concentration of starch at which the slurry, on heating, may form a thick gel. When the LGC is low, it implies that a small amount of the sample flour can easily form a gel. The gel formed from the low LGC sample normally has a low nutrient density and it will be difficult to meet the nutrient requirement of the young child. However, a high LGC value implies that the gruel will be formed with high quantity of the flour which is desirable for child feeding because it will enhance the nutrient density. The malting of sorghum grains might have resulted in the reduction of hydrophilic sites of the starch granules thereby reducing the gelling capacity (Moorthy et al., 1996). Thus, the gruel is liquefied, making it possible for more solid per unit volume to be added while maintaining the same consistency (Brandtzaceg et al., 1981).

Pasting properties of weaning food blends from sorghum varieties

Kinsella (1979) reported that protein gels are composed of three dimensional matrices or networks of interwoven and partially associated polypeptides in which the water is trapped. Gels are characterized by a relatively high viscosity, plasticity and elasticity. The pasting characteristics of the weaning food blends from local, improved and hybrid sorghum grains are presented in Table 3. The peak viscosity (PV) of the blends ranged between 130.2 and 532.1 RVU with Hybrid-(M10) and *Pelipeli*-(M0) having the lowest and highest values, respectively, at significant level of $p \leq 0.05$. Inclusion of malted flour resulted in a reduction of the PV of the blends. The observed decrease in PV can be attributed to the presence of malt which contains degraded starch through the malting process. The reduction in the viscosity of the malted diet is as a result of the activity of

Table 3. Pasting properties of weaning food blends from sorghum varieties.

Source of weaning food blend	Pasting properties						
	Peak viscosity (RVU)	Trough (RVU)	Breakdown viscosity (RVU)	Final viscosity (RVU)	Setback viscosity (Difference between final viscosity and trough; RVU)	Pasting temperature (°C)	Peak time (min)
Local sorghum grain:							
Pelipeli- (M0)	532.1±4.2[a]	335.3±2.4[a]	92.2±1.1[b]	826.2±5.2[a]	490.9±3.1[c]	88.6±0.3[ab]	5.01±0.01[c]
Pelipeli- (M5)	390.3±1.2[c]	173.1±2.1[d]	46.3±2.4[d]	689.1±2.4[b]	516.0±2.3[b]	87.1±0.2[ab]	4.53±0.02[e]
Pelipeli- (M10)	334.2±1.4[d]	142.1±1.1[e]	97.4±3.1[a]	576.3±2.1[c]	434.2±1.5[e]	85.3±1.5[b]	4.36±0.02[f]
Improved sorghum grain:							
Samsorg 17- (M0)	526.2±3.3[b]	294.2±2.1[b]	48.2±1.1[d]	391.2±4.7[d]	97.0±3.4[a]	89.6±2.2[a]	5.46±0.04[a]
Samsorg 17- (M5)	273.1±1.4[g]	143.1±2.2[e]	41.3±1.2[e]	229.3±3.1[f]	86.2±2.7[h]	88.3±3.1[ab]	5.13±0.05[b]
Samsorg 17- (M10)	163.2±1.2[h]	111.3±2.1[f]	59.1±2.1[c]	175.4±3.2[g]	64.1±2.9[g]	86.3±2.1[ab]	3.66±0.06[g]
Hybrid sorghum grain:							
Hybrid- (M0)	310.3±3.2[e]	181.2±3.2[c]	28.3±1.1[g]	248.2±3.8[e]	67.0±3.2[h]	86.4±2.4[ab]	4.63±0.03[d]
Hybrid - (M5)	288.1±1.2[f]	102.1±3.1[g]	32.4±2.1[f]	177.1±3.1[g]	75.0±3.1[f]	84.9±2.1[b]	4.38±0.05[f]
Hybrid - (M10)	130.2±1.1[i]	73.2±1.1[h]	35.2±2.3[f]	160.2±3.1[h]	87.0±1.9[d]	84.5±3.1[b]	2.93.±0.01[h]

amylase enzymes developed during malting process which degrades the starch to simpler units (Fagbemi, 2007; Nnam, 2000). The reduction in viscosity of the diets is advantageous, the gruel prepared from it would be watery and more solid could be added; this will amount to adding more nutrients and energy which is better for the growing children. Similar enzymic breakdown was observed by Onweluzo and Nnabuchi (2009) and this was attributed to the inherent starch in sorghum possessing its viscosifying properties since it was modified during heating and fermentation. This is implication of this decrease in fermentation. This implication of this decrease permits the addition of higher quantity of the solid without a concomitant increase in viscosity. Viscosity values of the samples could probably be attributed to the starch moiety which was not ruptured by preprocessing to release assimilable sugars (amylose and amylopectin) for gelation and in turn increases the viscosity. During malting, starch degrading enzymes such as α-amylase, β-amylase, limit dextrinase and α-glucosidase are usually activated in the cereal kernel thereby leading to the production of dextrins of lower molecular sizes capable of exhibiting lower PV than that of native starch (Fincher, 1989). There was digestion of the starch by these amylases to dextrin and maltose. The amylases breakdown the starch moiety leading to formation of gel network. Ragaee and Abdel-Aal (2006) reported that during the holding period of the viscosity test, the material slurries are subjected to high temperature and mechanical shear, which further disrupt starch granules in the grains, resulting in amylose leaching out and alignment. The difference in the PV of the weaning food blends indicates that there were differences in the rate of water absorption and starch granule swelling during heating (Ragaee and Abdel-Aal, 2006). The importance of peak viscosity in weaning food is that it signifies the ability of the formulation to gel or not (Mazurs et al., 1957).

The breakdown viscosity of the weaning food blends ranged between 28.3 and 97.4 RVU with Hybrid-(M0) and *Pelipeli*-(M10) having the lowest and highest values, respectively, ($p \leq 0.05$). The breakdown viscosity is essentially a measure of the degree of paste stability or starch granule disintegration during heating (Dengate, 1984). Therefore, the weaning food blends from the hybrid sorghum grains with relative low breakdown viscosity (28.3-35.2 RVU) will have a more stable paste during heating than others with higher breakdown viscosity (Farhat et al., 1999). However, the inclusion of sorghum malt in the blends tends to generally increase the breakdown viscosity thereby making the paste less stable during heating. This period is commonly associated with a breakdown in viscosity. The ability of starch to withstand heating at high temperature and shear stress is an important factor in many processes. Elofsson et al. (1997) noted that gel formation of proteins is the result of a two-step process involving, first, the partial denaturation of individual proteins to allow more assess to the reactive side groups within the protein molecules and second aggregation of these proteins by means of reactive side groups into a continuous three dimensional network structure capable of retaining significant amount of water and also exhibiting same structural rigidity. This phenomenon is of importance in foods since it contributes significantly to the textural and rheological properties of various foods.

The final viscosity of the weaning food blends ranged between 160.2 and 826.2 RVU with Hybrid-(M10) and *Pelipeli*-(M0) giving the lowest and highest values, respectively, ($p \leq 0.05$). The inclusion of sorghum malt in the weaning food blends was observed to cause general reduction in the final viscosity. This observation may be attributed to the enzymatic activity that had occurred in the sorghum malt during the malting process whereby the starch molecules were degraded (Juhasz et al., 2005; Xu et al., 2012). Consequently, the degraded starch structure (particularly amylose structure) resulted in reduced final viscosity due to minimized aggregation of the amylose molecules in the gelatinized paste during cooling (Chung et al., 2012). It had also been observed that the exhibition of final viscosity in a gelatinized paste is as a result of the aggregation of the amylose molecules in the paste (Miles et al., 1985). Since the viscosity of infants weaning food plays an important role in the food acceptability as well as on infants' energy intake (Treche and Mbome, 1999), the inference that can be made from these observations is that the weaning food blends from samples Hybrid-(M10), Samsorg 17-(M10) and Hybrid-(M5), which exhibited relative low final viscosity values, might be the most appropriate for developing weaning foods. Final viscosity is usually regarded as an indicator of the stability of the cooked paste in actual use (Ragaee and Abdel-Aal, 2006).

The setback viscosity of the weaning food blends ranged between 64.1 and 516.0 RVU with Samsorg 17-(M10) and *Pelipeli*-(M5) giving the lowest and highest values, respectively. The weaning food blends from both improved and hybrid sorghum grains had relatively low setback viscosity than that from the local sorghum grains. This phase is commonly described as the setback region and is related to retrogradation and reordering of starch molecules. The low setback values indicate low rate of starch retrogradation and syneresis. The peak viscosity often correlates with quality of end product and also provides an indication of the viscous. The setback viscosity is usually regarded as an index of retrogradation tendency of the paste prepared from a starchy food (Sandhu et al., 2007) and the higher the value, the greater the retrogradation tendency. However, the inclusion of sorghum malt in the weaning food blends tends to reduce the setback viscosity when compared with the ones without malt. Ragaee and Abdel-Aal (2006) had earlier reported that low setback values indicate low rate of starch retrogradation and syneresis. Therefore, the observed variation in setback values has a strong implication on the variability of retrogradation tendency of the weaning food paste during storage. The deduction that can be made from these observations is that the weaning food blends from samples Samsorg 17-(M10), Hybrid-(M0) and Hybrid-(M5), which exhibited relative low setback viscosity values, might be the most appropriate for developing weaning foods.

The pasting temperature of the weaning food blends ranged between 84.5 and 89.6°C with Hybrid-(M10) and Samsorg 17-(M0) having the lowest and highest values, respectively, ($p \leq 0.05$). Sorghum malt inclusion in the blends resulted in a reduction in the pasting temperatures. The differences in the pasting temperatures of the weaning food blends indicate that the blends exhibited different gelatinization temperatures (Newport-Scientific, 1996). The pasting temperature provides an indication of the minimum temperature required to cook a given sample, which can also have implications on energy usage (Ragaee and Abdel-Aal, 2006). The ability of protein to form gel and provide a structural matrix for holding water, flavours, sugars and food ingredients is useful in food application. Protein gel formation usually requires prior heating denaturation or unfolding of the polypeptide chain.

The peak time of the weaning food blends ranged between 2.93 and 5.46 min with Hybrid-(M10) and Samsorg 17-(M0) having the lowest and highest values, respectively, ($p \leq 0.05$). Sorghum malt inclusion in the blends resulted in a decrease in the peak time. The peak time is usually regarded as an indication of the total time taken by each blend to attain its respective peak viscosity. Thus, weaning food blends with a lower peak time will cook faster than that with a higher peak time.

CONCLUSION

This study has shown that sorghum malt flours can be used to improve the physicochemical and rheological properties of cereal-based weaning food blends. Both the water holding capacity and viscosity of the blends decreased as the concentration of malt inclusion was increased. However, the least gelation concentration of the blends was increased with an increase in the quantity of malt inclusion. Almost all the pasting factors of the weaning food blends, except the breakdown viscosity, got reduced with the inclusion of sorghum malt. Specifically, the weaning food blends from Samsorg 17-(M10) and Hybrid-(M5) could be regarded as appropriate formulations for developing weaning foods due to the exhibited characteristics of relative low final viscosity, setback and pasting temperature.

Conflict of Interests

The authors have not declared any conflict of interests.

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