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Research Article
Chemical, Functional, Pasting and Sensory Properties of Sorghum-Maize-Mungbean Malt Complementary Food

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Abstract

Background and Objective: The use of legume malt flour in partial replacement of cereals grain in complementary food formulation can improve the nutrient contents but may affect other properties of the products. This study aim at producing complementary food from blends of roasted maize, sorghum and mungbean malt and determine the nutrient and sensory properties of the products. **Methodology:** Maize, sorghum and mungbean grains were steeped in water for 9 and 6 h, respectively and subsequently malted for 48 and 72 h, respectively. The malts were roasted in an oven at 120°C for 15 min prior to milling and sieving. The resulting flours were used to prepare 70:0:30, 0:70:30 and 35:35:30 Maize:Sorghum:Mungbean malt complementary foods. Chemical, functional, pasting and sensory properties of the blends were analyzed. **Results:** The protein, fat, ash, crude fibre and moisture contents of the food blends ranged from 13.99-17.19, 1.50-1.58, 2.10-3.23, 3.30-3.92 and 6.35-8.42%, respectively. All the blends showed good capacity for water and oil absorption, bulk density and least gelation concentration. Sensory score of the samples showed that the complementary food blends were most preferred when consumed with sugar and milk compared to when consumed with sugar only or without milk. Maize:Sorghum:Mungbean malt (70:0:30) complementary food had the highest scores for colour, consistency, flavour and overall acceptability. **Conclusion:** The study shows that nutrient rich complementary food of acceptable quality can be produced from blends of roasted maize and mungbean malt with low cost technologies (malting and roasting) adaptable at rural community.

Key words: Mungbean malt, complementary food, chemical composition, sensory properties

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Complementary foods are foods either liquid or solid given to infants while still breast feeding to ensure optimal physical and mental development and it starts when the child is 4-6 months until 23 months. WHO[1] and Iwe[2] noted that in developing countries complementary foods are mainly formulated from starchy tubers like cocoyam, sweet potatoes and cereals like maize, millet and sorghum which are given to children as formulated gruels that are either mixed with boiled water or mashed. The porridge are associated with problems like thickening which results in eating difficulties or watery porridge with diluted nutrients if much dilution is applied, thus resulting in babies not meeting their nutritional and energy needs[1]. In addition, weaning period is the most critical period in a child's life as the transition of infants from nutritious and uncontaminated breast milk to the regular family diet creates a chance of vulnerability to malnutrition and disease for the child[3,4].

The need to formulate and develop a high protein and energy providing food for infants cannot be over emphasized as it will help to alleviate the endemic problem of protein-energy malnutrition among infants as industrially processed and packaged complementary foods by multinationals in Nigeria are costly. As a way of checking for this problem, the production of complementary food from locally available and acceptable nutrient rich food items using traditional processing such as malting, fermentation and roasting has been recommended[3,5,6]. Germinated and roasted cereals and legume may be advantageous in preventing the thickening problem, reduction of antinutrients contents which could lead to increases in nutrient absorption, adding germinated flour to cooked thick porridge may also make it safe and easier for the child to eat.

The consumption of cereal based food products formulated from maize and sorghum is very common and popular in Nigeria and these crops are produced in significant quantities in the country each year. Maize (*Zea mays*) is the fifth most produced commodity in Nigeria with an average production of 10 million metric tonnes per annum[7] which makes it readily available for use in product formulations. Sorghum (*Sorghum bicolor*) is an important source of vitamin B-complex and some other minerals like phosphorous, magnesium, calcium and iron. However, cereals are generally low in protein and are deficient in the essential amino acids lysine and tryptophan. Legume sprouting had long been adopted as a traditional technology to increase energy and nutrient density in formulating local complementary foods.

Incorporation of legume malt such as mungbean (*Vigna radiata*) to cereals may improve the protein content, functionality and other nutrient of complementary food and also help solve the problem of protein-energy malnutrition. Several reports existed on the production of complementary foods from local raw materials[2]. Desalegn *et al*.[8] and Victor *et al*.[9] produced complementary food from maize alone and maize and defatted fluted pumpkin flour, respectively while Shiriki *et al*.[10], reported the production of complementary food from maize and soybean. The objective of the study was to evaluate the chemical, functional, pasting and acceptability of complementary food from blends of roasted maize, sorghum and mungbean malts.

MATERIALS AND METHODS

Source of raw materials: Yellow maize (*Zea mays*) grains, sorghum (*Sorghum vulgare*) grains and mungbean (*Vigna radiata*) grains were purchased from 'Ogige' Market, Nsukka, Enugu State, Nigeria. All chemicals were of analytical grades.

Preparation of roasted maize and sorghum malt flour: Maize and sorghum grains were cleaned, weighed in lots of 200 g into malting bags and steeped separately in water (1:3 w/v) for 9 h. The steeped grains were then spread in a dark room to germinate for 48 h, followed by sun drying for another 48 h. After drying, the sprouts were removed by abrasion (rubbing in-between the palms). The maize malt was winnowed, roasted in an oven (Preiser Model, USA) at 120°C for 10 min, milled with a hammer mill and sieved (mesh size 200 μm) to obtain the roasted maize malt flour.

Preparation of roasted mungbean malt flour: Mungbean grain were cleaned, weighed in lots of 200 g into malting bags, steeped in water (1:3 w/v) for 3 h, air rested for 90 min, re-steeped in water for another 3 h, spread in a dark room to germinate for 72 h and sun dried for 24 h. The dried mungbean malt was dehulled by abrasion in-between the palms and roasted in an oven (Preiser Model, USA) at 120°C for 15 min followed by milling with a hammer mill and sieving (mesh size 200 μm) to obtain the roasted mungbean malt flour.

Blends formulation: The flours were used to prepare complementary foods in the ratios of 70:0:30, 0:70:30 and 35:35:30 maize-sorghum-mungbean malt blends.

Analysis

Proximate composition determination: The moisture, crude protein (N×6.25), ash, crude fat, crude fibre and carbohydrate

(by difference) of the samples were determined according to the method of AOAC[11]. All proximate analyses were carried out in triplicate and reported in percentage.

Determination of energy value of the complementary food: The energy value of the complementary food sample was estimated using Atwater conversion factor[12]. The fat value of each sample was multiplied by (9), protein value multiplied by (4) and carbohydrate value multiplied by (4). The sum of each of these values gave the energy value of the sample.

Anti-nutrient content: Phytates was determined as described by Latta and Eskin[13]. To 5 g of sample was added 50 of 0.8 M HCl solution for phytic acid extraction under orbital agitation (1300 rpm) for 1 h. The mixture was separated by centrifugation at 2800 rpm for 10 min. The supernatant eluted in ion-exchange chromatography column (0.50 g of Dowex-AGX-4 resin dissolved in 5 mL of deionized water) was used to prepare the stationary phase and 10 mL of deionized water was use for elution followed by 10 mL of NaCl 0.7 M solution and again with 10 mL of deionized water. The supernatant 1 mL was diluted to 25 mL with deionized water, of which 2 mL was eluted in the column with 10 mL of 0.1 M NaCl solution, followed by 10 mL of 0.7M NaCl solution. The last aliquot was collected and 3 mL of the eluent was reacted with 1 mL of the Wade reagent (ferric chloride 0.03% and sulfosalicylic acid 0.3%). The absorbance was measured at 500 nm in a UV-visible spectrophotometer. The concentration of phytic acid standard curve varied between 6.6 and 39.8 mg mL^{-1}.

Determination of tannin: Tannin content was determined by the Folis-Denis colorimetric method described by Kirk and Sawyer[14]. Sample (5 g) was dispersed in 50 mL of distilled water and shaken. The mixture was allowed to stand for 30 min at 28°C, filtered through Whatman No 42 grade of filter paper. The extract (2 mL) was dispersed into a 50 mL volumetric flask. Also 2 mL standard tannin solution (tannic acid) and distilled water (2 mL) were added in separate volumetric flasks followed by addition of reagent to each flask to serve as standard. Saturated Na_2CO_3 solution (2.5 mL) was added. The content of each flask was made up to 50 mL with distilled water and allowed to incubate at 28°C for 90 min. Their respective absorbance was measured in a spectrophotometer at 260 nm using the reagent blank to calibrate the instrument at zero.

Determination of oxalate: Oxalate content of the sample was determined by the method described by Onwuka[15]. Two gram

(2 g) of the sample was suspended in 190 mL distilled water in a 250 mL volumetric flask, followed by the addition of 10 mL of 6M HCl at 100ºC for 1h. The digested sample was cooled and made up to 250 mL mark before filtration. Triplicate portion of 125 mL of the filtrate was measured into beakers and three drops of methyl red indicator was added. This was followed by the addition of conc. NH_4OH solution until the test solution changes from salmon pink colour to a faint yellow colour. Each portion was heated again to 90°C and 10 mL of 5% $CaCl_2$ solution was added while being stirred continuously. It was cooled and left overnight at 5°C. The solution was centrifuged at 2500 rpm for 5 min. The supernatant was decanted and the precipitate completely dissolved in 10 mL of 20% H_2SO_4 solution. The filtrate resulting from precipitation was made up to 300 mL. Filtrate (25 mL) was heated until near boiling point and then titrated against 0.05 M standardized $KMnO_4$ solutions to faint pink colour which persists for 30 sec.

Alkaloid determination: Alkaloid content was determined gravimetrically by the method described by Harborne[16]. A measured weight of the sample was dispersed in 10% acetic acid solution in ethanol to form a ratio of 1:10 (10%). The mixture was allowed to stand for 4 h at 28°C. It was later filtered via Whatman no 42 grade of filter paper. The filtrate was concentrated to one quarter of its original volume by evaporation and treated with drop wise addition of conc. aqueous NH_4OH until the alkaloid was precipitated. The alkaloid precipitated was received in a weighed filter paper, washed with 1% ammonia solution dried in the oven at 80°C. Alkaloid content was calculated and expressed as a percentage of the weight of sample analyzed.

Saponin determination: Saponin was determined by the methods described by Obadoni and Ochuko[17]. Each sample (20 g) was added into a conical flask followed by the addition of 100 mL of 20% aqueous ethanol. The flask and its content was heated on a hot water bath for 4 h with constant stirring at 55°C, filtered and the residue extracted further with 200 mL 20% ethanol. The combined extract was evaporated on a hot water bath at about 90°C until 40 mL volume was achieved. Diethyl ether (20 mL) was added to the concentrate in 250 mL separator funnel followed by vigorous shaking. The aqueous layer was recovered while the ether layer was discarded. The purification process was repeated. N-butanol (60 mL) was added and washed twice with 10 mL of 5% aqueous sodium chloride. The remaining solution was heated in a water bath after which the sample was dried in oven, weighed and saponin content was calculated as percentage.

Determination of bulk density: The bulk density of the flour sample was determined by the method of Okaka and Potter[18]. A previously weighed measuring cylinder was filled to the 10 mL mark with the sample. The bottom of cylinder was tapped gently but repeatedly on a laboratory bench until there was no further reduction of the sample level The cylinder, together with the sample was weighed and bulk density was expressed as:

$$\text{Bulk density}\,(\text{g cm}^{-3}) = \frac{W_2 - W_1}{V}$$

Where:
BD = Bulk density in (g cm^{-3})
W_1 = Weight of empty cylinder (g)
W_2 = Weight of cylinder+sample (g) and
V = Volume of cylinder occupied by the sample (cm^3)

Determination of least gelation concentration: Gelation capacity was determined using the method as described by Onwuka[15]. A sample suspension of 10% (w/v) was prepared in 5 mL distilled water in test tubes. The sample test tubes was heated for 1 h in a boiling water bath followed by rapid cooling under running cold water. Further cooling of the test tubes was for 2 h at 4°C. The least gelation concentration was taken as the concentration when the sample from the inverted test tube did not fall or slip.

Determination of water absorption capacity (WAC): Water absorption capacity of the complementary food sample was determined by the modified method of Gandhi and Srivastava[19]. One gram (1 g) of the sample was mixed with 10 mL distilled water in centrifuged tubes and then allowed to stand for 30 min. Samples were centrifuged at 3000 rpm for 30 min. The supernatant was discarded, the tube weighed and water absorption was calculated with the expression.

$$\text{WAC} = \frac{W_2 - W_1}{W_0}$$

Where:
W_o = Weight of dry sample (g)
W_1 = Weight of tube and dry sample (g) and
W_2 = Weight of tube+sediment (g)

Determination of oil absorption capacity (OAC): The centrifugal method of Beuchat[20] was used to determine the oil absorption capacities of the formulated complementary food. Each sample (1 g) was mixed with 10 mL distilled water/oil for 30 sec. The samples were then allowed to stand at 28°C for 30 min, centrifuged at 5000 rpm g for 30 min and the volume of the supernatant noted in a 10 mL graduated cylinder. Density of oil (Soya cooking oil) was found to be 0.89 g mL^{-1}. Result was expressed on a dry weight basis.

Pasting properties determination: Pasting characteristics were determined with a rapid visco analyzer (RVA) (Model RVA 3D, Newport Scientific Australia). Each of complementary food blends (3 g) was first weighed into a dried empty canister, then 25 mL of distilled water was dispensed into the canister containing the sample. The solution was thoroughly mixed and the canister was well fitted into the RVA as recommended. The slurry was heated from 50-95°C with a holding time of 2 min followed by cooling to 50°C with 2 min holding time. The rate of heating and cooling were at a constant rate of 11.25°C/min. Peak viscosity, trough, breakdown, final viscosity, set back, peak time and pasting temperature were read from the pasting profile with the aid of thermocline for windows software connected to a computer[21].

Sensory evaluation: The complementary food blends from roasted maize, sorghum and mungbean malts were evaluated for taste, colour, mouthfeel, flavour, consistency, after taste and overall acceptability using thirty women panelist of child bearing age, who are acquainted with complementary food on a 9 point Hedonic scale as described by Ihekoronye and Ngoddy[12]. Three portion of each complementary food blends were weighed. The first portion was blended with sugar and milk, the 2nd portion with sugar only and the third portion with neither sugar nor milk. This was followed by reconstituting 6 g each with 50 mL of hot water.

Statistical analysis: The experimental design was completely randomized design. All data generated was subjected to one-way analysis of variance (ANOVA) and means were separated using least significant difference (LSD) and significance was accepted at $p < 0.05$.

RESULTS

Proximate composition of maize-sorghum-mungbean malt complementary food blends was shown in Table 1. Moisture content of the blends ranged between 6.35 and 8.42%. Protein content ranged from 13.99-17.19%. Blend having 70% malted maize, 0% malted sorghum and 30% mungbean malt (70:0:30) had highest protein content compared to others. Fat contents of the samples were generally low ranging from 1.50-1.58% and are not within

Table 1: Chemical and functional properties of maize-sorghum-mungbean complementary food blends

| Parameters | Maize:Sorghum:Mungbean malt complementary food blends | | | LSD Value |
	70:0:30	0:70:30	35:35:30	
Proximate composition (%)				
Moisture	6.35±0.03[a]	8.38±0.03[b]	8.42±0.03[b]	0.67
Protein	17.19±0.74[c]	15.79±0.74[b]	13.99±0.74[a]	0.09
Fat	1.50±0.03[a]	1.50±0.03[a]	1.58±0.03[b]	0.19
Crude fibre	3.30±0.03[a]	3.72±0.03[b]	3.90±0.03[c]	0.15
Ash	2.35±0.03[a]	2.10±0.03[a]	3.23±0.03[b]	1.00
Carbohydrate	69.31±0.48[a]	68.51±1.15[a]	68.88±0.95[a]	0.44
Energy value (kcal)	372.94	363.18	356.10	
Anti-nutrient content (mg/100 g)				
Tannin	0.61±0.03[c]	0.29±0.05[a]	0.55±0.04[b]	0.13
Saponin	0.48±0.03[a]	1.29±0.02[b]	1.55±0.01[c]	1.00
Oxalate	1.48±0.02[b]	1.59±0.12[b]	1.30±0.05[a]	0.12
Phytate	1.19±0.04[a]	5.30±0.44[b]	1.09±0.04[a]	0.65
Alkaloid	5.07±0.05[c]	2.10±0.05[a]	3.36±0.05[b]	1.00
Functional property				
Water absorption capacity (mL/100 g)	135.50±0.70[a]	152.00±1.41[b]	165.50±6.36[c]	1.00
Oil absorption capacity (mL/100 g)	142.00±2.82[a]	160.00±1.00[b]	175.50±1.41[c]	1.00
Bulk density (g cm^{-3})	0.70±0.00[a]	0.70±0.00[a]	0.70±0.00[a]	1.00
Least gelation concentration (% w/v)	18.50±0.50[b]	16.00±0.30[a]	16.50±0.70[a]	0.29

Values are means of triplicate determinations±Standard deviation. Means with different superscript in the same row are significantly (p<0.05) different

Table 2: Pasting properties of maize-sorghum-mungbean malt complementary food blends

Maize:Sorghum:Mungbean malt flour	PV (RVU)	TV(RVU)	BD (RVU)	FV (RVU)	SB (RVU)	PT (min)	T (°C)
0:70:30	127±0.03[a]	105±0.02[a]	22±0.01[b]	281±0.04[a]	76±0.02[a]	5.20±0.15[a]	81.10±0.13[a]
70:0:30	298±0.05[c]	290±0.08[c]	8±0.03[a]	512±0.13[c]	222±0.03[b]	6.87±0.22[b]	88.05±0.02[b]
35:35:30	268±0.11[b]	247±0.28[b]	21±0.10[b]	406±0.08[b]	159±0.06[c]	5.13±0.02[a]	89.60±0.05[b]

Values are means of 3 replications±Standard deviation, PV: Peak viscosity, TV: Trough viscosity, BD: Breakdown viscosity, FV: Final viscosity, SB: Setback viscosity, PT: Peak time and T: Pasting temperature, Means with different superscripts in the same column are significantly (p<0.05) different

RDA values of 10-25 g for infants up to 1 year of age. Carbohydrate content ranged from 68.51-69.31% and the energy value ranged from 356.10-372.94 kcal/100 g with blend having 70% malted maize, 0% malted sorghum and 30% mungbean malt (70:0:30) having the highest values for each.

Tannin content of the samples ranged from 0.29-0.61 mg/100 g (Table 1). Tannin was lowest in 70:0:30 (Maize:Sorghum:Mungbean malt) blend in comparison to 0:70:30 and 35:35:30 and the difference was significant (p<0.05). Sample containing highest quantity of sorghum (70:0:30) had highest tannin content. More saponin (1.29 mg/100 g) was observed in sample containing 70% malted maize, 0% malted sorghum and 30% mungbean malt (70:0:30) compared to sample containing 0% malted maize, 70% malted sorghum and 30% mungbean flour (0.48 mg/100 g). Oxalate content of samples was low ranging from 1.30-1.59 mg/100 g combining sorghum and maize malt in equal amount (35:35:30) gave the highest saponin value (1.55 mg/100 g), lowest phytate and oxalate (1.09 mg and 1.30 mg/100 g, respectively) values. Alkaloid content of the samples ranged from 0.21-0.51 mg/100 g.

Water and oil absorption capacities ranged from 135.50-165.50 and 142.00-175.50 mL/100 g, respectively with 35:35:30 (Maize:Sorghum:Mungbean malt) food blend having the highest value for both parameters (Table 1). Least gelation concentration ranged from 16.00-18.50% w/v with the 70:0:30 (Maize:Sorghum:Mungbean malt) blend having the highest value.

The Pasting properties of formulated maize-sorghum-mungbean malt complementary food blends were shown in Table 2. Significant differences (p<0.05) in pasting properties among different complementary food blends were observed. Among the blends, 70:0:30 (Maize:Sorghum:Mungbean malt) exhibited the highest peak viscosity (PV), trough viscosity (TV), final viscosity and setback (SB) viscosity values. Blending of the maize and sorghum malt in equal amount increased the PV, TV, FV, SB and pasting temperature than Maize:Sorghum:Mungbean malt (0:70:30) blend. Lowest breakdown viscosity (BD) value of 8.00 RVU was observed in the 70:0:30 blend. The pasting temperature, which is the temperature at which starch attains peak viscosity when heated with water to form a paste ranged from 81.00-89.60°C. The peak time for the samples ranged from

Table 3: Sensory scores of maize-sorghum-mungbean malt complementary food blends

Maize:Sorghum:Mungbean malt	Colour	Consistency	Flavour	Taste	Mouthfeel	Aftertaste	Overall acceptability
With milk and sugar							
70:0:30	7.45±0.05[b]	7.95±0.02[c]	6.95±0.22[b]	7.25±0.15[c]	6.75±0.25[a]	7.67±0.26[a]	7.65±0.05[c]
0:70:30	6.95±0.30[a]	6.35±0.16[a]	6.55±0.17[a]	6.75±0.30[a]	6.73±0.06[a]	7.25±0.15[a]	6.45±0.20[a]
35:35:30	7.45±0.21[b]	7.00±0.04[b]	6.75±0.21[a]	6.88±0.08[b]	6.76±0.14[a]	7.55±0.05[b]	7.45±0.16[b]
With sugar only							
70:0:30	6.69±0.15[b]	6.95±0.08[c]	6.85±0.25[b]	6.80±0.21[c]	6.55±0.31[a]	6.65±0.25[c]	6.85±0.05[c]
0:70:30	5.98±0.05[a]	5.35±0.25[a]	5.65±0.12[a]	5.75±0.18[a]	6.51±0.18[a]	6.20±0.26[a]	6.45±0.26[a]
35:35:30	6.65±0.02[b]	6.80±0.11[b]	6.77±0.08[b]	6.45±0.25[b]	6.50±0.25[a]	6.45±0.17[b]	6.65±0.23[b]
Without milk and sugar							
70:0:30	5.95±0.13[b]	6.45±0.31[c]	6.75±0.23[c]	6.52±0.31[c]	6.55±0.35[a]	6.45±0.31[c]	6.75±0.17[c]
0:70:30	5.45±0.03[a]	5.15±0.25[a]	5.50±0.04[a]	5.25±0.05[a]	6.53±0.05[a]	6.23±0.12[a]	6.12±0.30[a]
35:35:30	5.85±0.25[b]	6.00±0.13[b]	6.65±0.07[b]	6.35±0.06[b]	6.55±0.12[a]	6.30±0.11[b]	6.55±0.15[b]

Values are mean of 30 panelist±Standard deviation. Means with different superscript in the same column are, significantly (p<0.05) different

5.13-6.87 min. Combining maize-sorghum-mungbean malt in the ratio (35:35:30) increased the cooking temperature but reduced the cooking time.

The sensory scores of maize-sorghum-mungbean malt complementary food blends, blends with sugar only and sugar with milk are shown in Table 3. The lowest sensory score for colour by the panelist was observed in sample 0:70:30 while the blends 35:35:30 and 70:0:30 scored equally in colour attribute. The food blend (70:0:30) was preferred by the panelist in attributes of flavour, taste, aftertaste and overall acceptability, however, there were no significant (p>0.05) difference in scores for mouthfeel. Incorporation of sugar and milk combine with sugar increase the level of preference in all the attributes except for mouthfeel. Based on blending ratios, the 70:0:30 blends had highest scores for colour, taste, flavour and overall acceptability. There was no significant (p 0.05) difference in the sensory score for colour, taste and overall acceptability of the 70:0:30 and 35:35:30 blends. All the other samples recorded relatively good sensory scores.

DISCUSSION

The moisture content of the blends was within RDA values (5-10%) for moisture content of complementary foods[22]. The low moisture content of the blends (<10%) will ensure their shelf-life stability. Composition differences affected the protein content of the blends. The values of protein observed in this study were within the range reported by other researchers. However, Akinola et al.[23] reported higher protein value when Maize: Sorghum: Pumpkin seed flour was combined in the ratio of 70:5:25. The lower value of protein observed in this study could be attributed to effects of heat treatment after soaking and germination as reported by Uppal and Bains[24]. Khalil et al.[25] also reported decrease in protein content after cooking of field pea, moth pea and pigeon pea.

The protein content of the complementary food blends are within RDA values (13-14 g) for infants as recommended by National Research Council[22]. The low fat content may also be attributed to malting loss incurred as a result of dry matter loss, mainly due to growth and respiration of the embryo and the enzymatic activities in the grains as reported by Abiodun[26]. Uppal and Bains[24] also reported reduction in fat content of germinated mungbean, chickpea and cowpea. Vegetable oil can be incorporated in the complementary food during consumption to improve the palatability, increase the energy density and absorption of fat soluble vitamins. Low crude fibre of the food blends (3.30-3.90%) can be attributed to the fact that fibre in the hull was removed during processing. Genc et al.[27] noted that cereal hulls contain about 64% of the total fibre. Ash content which is an index of the mineral content of food samples ranged from 2.10-3.23% and this falls within the RDA values (not less than 2% and not more than 5%) for infants up to 1 year of age recommended by (NRC)[22]. Infants need minerals for their growth and development which can be supplied by these products. The energy specification for complementary food intake is 350 kcal/100 g daily for a child up to 1 year of age[12]. Hence the processed complementary food can meet the energy requirement of infant.

Lowest tannin of sample 70:0:30 (Maize:Sorghum:Mungbean malt) could be due to high content of maize flour which contains little or no tannin[23]. Tannin usually forms insoluble complexes with protein thereby interfering with its bioavailability and high tannin in diets can bind with proteins of saliva and mucosal membrane. The tannin content of the samples was within acceptable levels. Aletor and Adeogun[28], noted that tannin content as high as 76-90 g kg/dry matter could be detrimental if consumed. Yousif and Magboul[29], noted that phytate forms stable bonds with protein and may inhibit the activity of

enzymes such as amylases and proteases. Maize and sorghum have been reported to have lower endogenous phytase activity than cereals such as rye, wheat and barley among others. Germinated cereal flours can promote phytate hydrolysis when prepared as gruel for infant. The low tannins, saponins and phytate observed in this study can be attributed to soaking, dehulling and malting effects as these compounds are heat stable[30]. Although, there are currently no maximum levels for alkaloid for complementary food, it has been demonstrated that they may exert toxic effects in infants when taken in excess[31].

High water binding ability of flours limits the amount of water available. During mixing, free water can migrate towards water binding sites and thus increase the viscosity of the products. Khalid *et al.*[32] observed that heat treated flours tends to absorb more water due to gelatinization of carbohydrates and heat dissociation of proteins. Also proteins and starch have the tendency to bind water. Therefore, high protein content of the flour may possibly have affected its water binding property. Fat absorption property of flours on the other hand, has been known to be of importance in food formulation and sensory characteristics of food. Desalegn *et al.*[8] noted that high oil absorption capacity is important for increasing energy density of complementary foods. Bulk density was 0.70 g cm^{-3} for all the samples. Low bulk density observed in all the blends could be due to use of malted flour. Malting has been reported to reduce bulk density of complementary food thereby resulting in thinning effects of the gruel. Variation in the relative ratios of constituents like protein, lipids and carbohydrates may have influenced the observed least gelation concentration[33].

Pasting properties are important in predicting the behaviour of flours during and after cooking. The difference in PV observed in the samples is an indication of various degrees of starch gelatinization and difference in amylose content of the blends. Sanni *et al.*[34] noted that high PV is closely associated with the high starch damage which in turn enhances viscosity. The implication of this result is that the 70:0:30 (Maize:Sorghum:Mungbean malt) complementary food blend will have high gel strength and gel forming tendency during cooking or reconstitution compared to the other blends. The extent of swelling was lowest in 70:0:30 blend implying that the blend may be suitable in the preparation of complementary food gruel. Maaran *et al.*[35] noted that PV is influenced by friction between swollen granules, amylose content and relative crystallinity. The higher BD of 0:70:30 and 35:35:30 indicates less ability to resist heating and shear stress during cooking. Setback viscosity is measured as the difference between the FV and

TV. Ambigaipalan *et al.*[36] reported that SB measures recrystallization of gelatinized starch during the cooling period and also reflects the interaction between leached amylose chains during the cooling cycle and presence of intact and/or fragmented granules embedded in the amylose network. The lower SB of 70:0:30 reflected extensive granule disruption during the heating cycle, which has been shown in the high value of PV, hence, minimum resistance to the stirring action of the paddles during the cooling cycle would be experienced. Final viscosity is the viscosity registered at the end of the cooking. Setback viscosity is the ability of the paste to retrograde, a phenomenon that causes firmness and increasingly resistant to enzyme attack. Adeyemi and Idowu[37], suggested that the higher the SB, the lower the retrogradation of the flour paste during cooling and staling rate of the product made from the flour. The high pasting temperature observed indicates that the blends had a high resistance to swelling and rupture possibly due to granule size and malting effects. According to Shimelis *et al.*[38], the pasting temperature provides an indication of the minimum temperature required for sample to cook and energy cost. The low peak time is an indicative of the ease of cooking of the product.

The lowest scores for sensory parameters observed for 0:70:30 (0% maize, 70% sorghum, 30% mungbean malt) blends could be attributed to the dark brown colour of sorghum. Addition of milk positively affected the product acceptance. The same trend was also observed for consistency, flavour, taste, aftertaste and overall acceptability. The high sensory scores recorded for the samples with sugar and milk is expected as milk and sugar add sweetness and flavour to food and this portrays the product as acceptable and of good sensory quality as complementary foods are majorly consume together with sugar and milk.

CONCLUSION

This study has shown that complementary food of acceptable quality can be produced from blends of roasted sorghum, maize and mungbean malt flours. Even though blending ratio affected the properties of the complementary food, all the samples evaluated showed good values for functional properties, proximate composition and pasting properties. Malting and roasting were significant in reducing the anti-nutrient content of the complementary food. The preferred complementary food blend was sample containing 70% maize and 30% mungbean malt, however, combination of sorghum and mungbean malt gave the lowest viscosity. The significance of this study lies in the application of low cost technology of malting and roasting in preparation nutritious

and acceptable complementary food using locally available mungbean and maize grain. The technology is easily adaptable among the rural and urban poor thus facilitating production of complementary foods and reduction in infant malnutrition.

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