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RESEARCH ARTICLE

DEVELOPMENT OF WEANING FOOD FROM WHEAT FLOUR SUPPLEMENTED WITH DEFATTED SESAME FLOUR

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Abstract: This study was conducted to produce high quality weaning food as complementary from local raw materials (Khartoum, Sudan), intended for feeding infants and young children generally from the age of 6 months to 24 months. Three diets A, B, C, and Cerelac (reference diet) were analyzed for their chemical composition, functional properties, microbial load and sensory quality. The results revealed significant differences ($P \leq 0.05$) in the biochemical composition of all diets. The formulated diets have high protein content than that of the reference diet. The study revealed that the protein digestibility ranged from 87.86 to 95.51 for formulated diets compared to reference diet (94.12%). Interestingly, with increasing the amount of sesame flour in the formula the content and scores of all amino acid, as well as the protein digestibility were significantly increased ($P \leq 0.05$). Iron content of the diets ranged from 5.14 to 14.05 mg/100g while that of the reference diet was11.24. For functional properties, the bulk density and water holding capacity was concurrently decreased ($P \leq 0.05$) with the increase in the sesame flour supplementation. All the diets were free from pathogenic bacteria and hence considered safe for consumption. Sensory evaluation of the studied diets showed that diet C acquired the highest score compared to other diets including the reference diet.

Keywords: Amino acids, functional properties, protein digestibility, sesame flour, weaning diets

Introduction

In most developing countries, the prevalence of undernutrition and micronutrient deficiencies is high among infants and young children aged 6 to 23 months, which increased the risk of underweight, stunt growth, and death at these ages (UNICEF, 2009). Ideally, all children in this age range are breastfed, however, when they get older, the energy and nutrient contribution of complementary food become increasingly necessary for meeting daily requirements. For many infant and young children, however, the small quantities of cereal-based porridges commonly fed to them do not contain enough energy and micronutrients to meet daily requirements (Nestel *et al.*, 2003). The generally accepted recommendations for improving the nutritional status of children in this age group are to feed children with locally available micronutrient-rich foods and encourage local production of low-cost industrially processed, fortified cereal-based complementary foods (Nestel *et al.*, 2003; UNICEF, 2012). Accordingly, formulation and development of nutritious weaning foods from local and readily available raw materials has received considerable attention in many developing countries. The commercially standardized foods are generally magnificent and can help meet the nutritional requirements of young children in both developed and developing countries (Asma *et al.*, 2006). However, the development of low-cost, high-protein food supplements for weaning infants is a constant challenge for developing countries (UNICEF, 2012). The high cost of weaning foods, vegetables, and animal protein, together with the unavailability of nutritious foods, adds more to the difficulty of providing good nutrition to children.

In Sudan, sorghum and wheat are the main staple foods while millet constitutes the main staple in Western Sudan and root crops such as cassava and yam predominate in the Southern Sudan. Weaned child in most parts of Sudan depends mainly on adult traditional foods (Dirar, 1993). Nevertheless, the major traditional weaning food used in Sudan was *Nasha* which is a thin porridge made from fermented sorghum flour usually containing not more than 10% dry matter with a reduced energy density of about 20-30 kcal/100g (ICN, 1993; Graham *et al.*, 1986). Mohamed *et al.* (1992) reported that the Sudanese mothers weaned their babies with different food such as milk products, lemon juice, custard, biscuits, and milk. This because all commercial weaning foods in Sudan are imported which are too expensive for low-income families. Moreover, because of poverty and illiteracy, commercial infant foods, when prepared at home, do not fulfill the nutritional requirement for children under 5 years of age because knowledge about food processing is limited and the processes applied may destroy nutrients (Asma *et al.*, 2006). Therefore, there is a real need to develop weaning formulation from local materials to overcome these problems and provide nutritious weaning foods with low cost that will be accessible to all sectors of the populations. These weaning foods should have good nutritional composition with high balanced protein and caloric values. With these requirements kept in mind, staple food materials such as wheat flour supplemented with sesame flour might be deliberated for the formulation of weaning foods.

Despite the fact that sesame is the third allergic food coming after milk and eggs (Dalal *et al.*, 2002), reports indicated that sesame-based complementary meals had significantly increased nutritional values and it is thus recommended for weaning and functional food formulations (Lalude and Fashakin, 2006; Ogungbenle and Onoge, 2014; Onabanjo *et al.*, 2009; Shuaibu *et al.*, 2015). In addition, sesame has numerous useful compounds such as mono and polyunsaturated fatty acids, plant protein, dietary fiber, phytochemicals, antioxidants, phytosterol, lignans, vitamins, and minerals (Asghar *et al.*, 2014; Kanu *et al.*, 2007). These compounds may help in the prevention and control of diseases such as cancer, cardiovascular disease, osteoporosis, oxidative stress and other degenerative diseases (Asghar *et al.*, 2014; Kanu *et al.*, 2007). These beneficial functional ingredients and rich nutritional composition of sesame may overcome its allergic effects and thus makes it an excellent component of functional food. Therefore, aim of this study was to formulate complementary diets from wheat and sesame flours to evaluate the nutritional and sensory qualities of the weaning food blends.

Materials and Methods

Materials. The reference diet Cerelac, (a commercial, fortified, instant porridge), was purchased from the local market, Khartoum, Sudan. Decorticated roasted white sesame seeds (*Sesamum indicum*) were obtained from Elturia sweet factory, Khartoum, Sudan, and then pressed using laboratory Screw Presser. The defatted seed were finally ground and kept in the refrigerator. Wheat grains (Wadi El Neel cultivar) seasons 2006/2007 were obtained from Dongola Research Station, Dongola, Sudan. The grains were cleaned and milled using the extraction mill at the Food Research Centre, Khartoum, Sudan. The resulted flour of 67% extraction rate was packed in plastic bags and kept in the freezer at -20°C until use.

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Formulating weaning food

Initially, wheat flour was subjected to treatments with porcine pancreatic α-amylase type VI-B (Sigma P-3176, 30 international units (IU), Sigma Chemical Co. Ltd., St. Louis, MO, USA) at the concentration of 200 mg/ kg.

Then, the treated wheat flour and defatted sesame flour were mixed with wheat flour: sesame flour at ratios of 90: 10 (diet A), 80:20 (diet B), and 70:30 (diet C). To this blend fixed amount of vanillin (flavoring agent), Sodium bicarbonate (flour treating agent), ascorbic acid (antioxidant agent), sodium chloride (taste agent), sugar, and skimmed milk powder were added (Table 1).

Thereafter, the blends were thoroughly mixed, suspended in water at ratio of 1: 2 (blends: water), and then made into dough. Then, the dough was spread into a thin sheet, baked on a hot plate, dried, manually grinded, and store at -20 for further analysis.

Table 1. *Formulations of weaning blends prepared from wheat and sesame flour and other ingredients (in grams)*

Weaning formula	Wheat flour	Sesame paste	Sugar	Skim milk	Vanillin	Ascorbic acid	NaCl	$NaHCO_3$
A	90	10	5	5	0.7	0.002	0.4	0.2
B	80	20	5	5	0.7	0.002	0.4	0.2
C	70	30	5	5	0.7	0.002	0.4	0.2

Chemical composition analysis

In this assay, the contents of moisture, protein, ash, fat, fiber and carbohydrate of wheat flour, defatted sesame flour, and the formulated diet were determined according to AOAC methods (2003). The energy values of samples were calculated using the Atwater nutrient conversion factors of 4, 9, and 4 kcal/g of the protein, fat, and carbohydrates, respectively.

Mineral determination

The contents of Na, K, Mg, Ca, P, Fe, Mn, and Zn in the diet were determined according to AOAC (2003). Analysis of all minerals was carried out on atomic absorption spectrophotometer Model GBC 932AA (GBC Scientific, Dandenong, Victoria, Australia) using an air–acetylene flame by AAS method with deuterium background correction. For all elements, the air and acetylene flow rates were kept at 13.5 L/min and 2.0 L/min, respectively.

Amino acid determination

The amino acids composition of the samples was measured on hydrolysates using amino acids analyzer (Sykam-S7130, Tokyo, Japan) based on high-performance liquid chromatography technique. Sample hydrolysates were prepared following the method of Moore and Stain (1963).

About 200 mg of the sample was taken in a hydrolysis tube. Then, 5 mL of 6 N HCl was added, and the tube tightly closed and incubated at 110°C for 24 h. After incubation, the solution was filtered, and 200 mL of the filtrate was evaporated to dryness at 140°C for 1 h. The hydrolysates after dryness were diluted with 1.0 mL of 0.12 M citrate buffer (pH 2.2). Aliquot of 150 µL of the sample hydrolysates was injected to the separation column at 130°C. Ninhydrin solution and an eluent buffer (solvent A, pH 3.45 and solvent B, pH 10.85) were delivered simultaneously to a high temperature reactor coil (16 m length) at a flow rate of 0.7 mL/min. The buffer⁄ninhydrin mixture was heated in the reactor to 130°C for 2 min to accelerate the chemical reaction of amino acids with ninhydrin. The products of the reaction mixture were detected at wavelengths of 570 and 440 nm on a dual channel photometer. The amino acids composition was calculated from the areas of standards obtained from the integrator and expressed as mg/100 g.

Chemical scoring of essential amino acids

The essential amino acids of weaning food formula were showed as percentage of the required amounts for infant children as recommended by FAO/WHO/UNU (1985).

In-vitro protein–digestibility

In vitro protein digestibility of raw materials and formulated diets was measured according to the method described by Manjula and John (1991) with minor modification. Briefly, a known weight of the sample containing 16 mg nitrogen was taken in triplicate and digested with 1 mg pepsin in 15 mL of 0.1 M HCl at 37°C for 2 h. The reaction was stopped by the addition of 15 mL of 10% trichloroacetic acid (TCA). The mixture was then centrifuged at 6300×g for 5 min. The mixture was then filtered quantitatively through Whatman No. 1 filter paper. The digestible protein in the TCA soluble fraction was analyzed for nitrogen using the micro- Kjeldahl method (AOAC, 2003) and expressed as a percent of the total N.

Protein efficiency ratio (PER)

It is computed from essential amino acids pattern suggested by FAO/WHO/UNU (1985) multiplied by their pepsin-pancreatic digestibility factor according to the set of equations proposed by Hsu *et al.* (1978).

Functional properties

The water holding capacity of the formulated diet was measured by the method of Quinn and Beuchat (1975). The water holding capacity is expressed as milliliters of water retained per 100g dry matter after centrifugation at 4400 × g for 20 min at room temperature. The apparent viscosity (AV) was determined as described by Quinn and Beuchat (1975).

Briefly, diet sample slurry (20%, w/v) was prepared by suspending 20 g sample in 100 mL distilled water. Then sample slurry was divided into two portions. One part was used without heating while the other was heated to 70 ºC for 15 min.

After equilibration to the room temperature (35 ºC), the apparent viscosity of the sample slurry was determined by using a Brookfield Synchro-electric Viscometer (Brookfield Engineering Laboratories, Stoughton, MA, USA) with spindle No.4 (20 rpm) and expressed as cent poise units (cp). The bulk density of weaning food formula was measured following the method of Wang and Kinsella (1976). The bulk density is expressed as gram sample per milliliters of the volume occupied.

Microbiological analysis

All media were obtained in a dehydrated form and stored in a hygroscopic environment in a cool and dry place away from light and prepared according to the manufacturer's instructions. The bacterial count was determined according to Houghtby *et al.* (1992) using standard plate count nutrient agar media. The plates were incubated at 37 ºC for 48 hours. Typical colonies in the selected dilution were counted (25-250 colonies in each dilution).

MacConkey broth purple medium was used for screening of coliform bacteria in diet samples. The *Salmonella* was cultivated on nutrient broth media. The mannitol salt agar media was used to screen for *Staphylococcus aureus*. For the determination of yeast and molds malt extract, agar media contained chloramphenicol (100 mg/L) was used. The plates were incubated at 30ºC for 48 h.

Sensory evaluation

The sensory characteristics of the diet were evaluated following the ranking test described by Ihekoronye and Ngoddy (1985). A trained panel of 19 members, composed of adult male (9; age ranged from 25 to 35) and female (10, age ranged from 26 to 40), was assigned to determine the quality of the formulated diet (colour, flavor, taste, texture, and overall acceptability).

Members were asked to score 1–5 hedonic scale (1 = poor, 2 = acceptable, 3= good, 4 = very good, and 5 = excellent). The samples were randomized and presented using tag for each one. The mean scores were analyzed by Duncan's multiple range tests to determine the differences in judges' response.

Statistical analysis

Statistical analysis was carried out using Statistical Analysis System (SAS) software. Three separate samples were analyzed, and mean values were calculated. The data were assessed by analysis of variance (ANOVA) and by Duncan's Multiple Range Test with a probability $P \leq 0.05$.

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Results and discussion

The chemical composition of raw flours and formulated diet

The chemical compositions of wheat flour, defatted sesame flour, and the diets are shown in Table 2. Analysis of variance revealed significant differences in the moisture, protein, fat, ash, fiber and carbohydrate content between wheat and defatted sesame flour. The highest caloric value of sesame flour compared to that of wheat flour is attributed to the high fat content of sesame four.

Table 2. *Chemical composition (%) and total energy (kcal/100 g) of wheat flour, sesame flour, and formulated diets*

Characters	Moisture	Protein	Oil	Ash	Fiber	Carbohydrates	Energy value
Ingredients							
Wheat flour	12.60±0.06 [a]	13.70±0.08 [b]	1.71±0.01 [b]	0.63±0.00 [b]	0.96±0.02 [b]	70.40±1.04 [a]	351.79±3.18 [b]
Sesame	3.65±0.01[b]	27.80±0.24 [a]	48.21±0.90 [a]	5.55±0.05 [a]	6.79±0.00 [a]	8.00±0.04 [b]	577.09±7.57 [a]
Formulated diet							
A	7.93±0.04[a]	18.42±0.01[c]	4.06±0.08[c]	1.47±0.06[c]	0.66±0.10[c]	67.47±0.08[b]	380.59±1.39[b]
B	7.97±0.05[a]	20.43± 0.01[b]	9.49±0.09[b]	1.50±0.01[c]	0.86±0.02[b]	59.74±0.11[c]	306.07±0.46[d]
C	6.74±0.05[b]	20.83± 0.01[a]	10.88±0.01[a]	1.93±0.03[b]	1.01±0.06[a]	58.60±0.08[d]	315.87±0.60[c]
Reference diet	2.78±0.03[c]	13.95± 0.01[d]	3.12±0.03[d]	2.67±0.04[a]	1.10±0.02[a]	76.37±0.03[a]	389.42±0.17[a]

Values are means ± standard deviation of triplicate samples. Means not sharing a common superscript letter in a column are significantly different at P ≤ 0.05.

The sesame flour has higher protein and fiber contents compared to that of wheat flour, whereas, the wheat flour has higher carbohydrate content than sesame flour. Expectedly, combining wheat flour with sesame flour improved the keeping quality of the flour by increasing the protein and fiber content and/or quality of the diet. Concerning the chemical composition of the formulated diet, the moisture content of the diets ranged from 6.74 to 7.93% that was significantly higher (P ≤ 0.05) than that of the reference diet (2.78%). There was no significant difference (P ≤ 0.05) in moisture content of diet A and B, whereas the moisture content of diet C significantly difference than those of diet A and B. The moisture content of the current study was within the range (5-10%) recommended by PAG (1975) and Mohamed (2004), but it was higher than the range 2.65-4.70 (Annan and Palhar, 1995; Asma *et al.*, 2006). These differences in moisture content may be attributed to the drying of the formulated diets. The protein content of formulated diets increased (P ≤ 0.05) with increasing the sesame flour supplementation, and it was 18.42, 20.43, and 20.83 for diets A, B, and C, respectively. The protein content of the formulated diets was significantly (P ≤ 0.05) higher than that of the reference diet 13.57% (Table 2).

Weaning foods used in supplementary feeding programs are recommended to contain 17-20% protein (Jansen and Harper, 1980). Higher level of protein is advisable for weaning food of entirely vegetable origin (FAO/WHO/ UNU, 1985). The protein content of the tested diets was higher than 16% specified by PAG (1975), but lower than 23%, the value recommended by the National Academy of Science (1989). The protein content of the diets was higher than the range of 14.8-15.6% reported by Wondimu and Malleshi (1996). The recommended daily intake of protein and energy for infant and small children below 2 years old are between 14-16 grams of protein and 820-1360 kilocalories, respectively (FAO, 1979). The fat content of the formulated diets were ranged from 4.06% in diet A to 10.88% in diet C (Table 2). All the diets acquired higher (P ≤ 0.05) content of fat than the reference diet which gained 3.03%. The codex standard for processed cereal-based foods for infants and young children recommend the fat content of the tested diet category not to exceed a maximum fat content of 3.3g/100kcal (Codex, 2006). This value is equivalent to 12.26, 10.10 and 10.42 for diet A, B, and C respectively. Thus, the fat content for the tested formulae were within the range recommended by the Codex (2006). The appropriate fat content of complementary food is recommended to give the formula good source of caloric value in addition to palatability and decreased consistency. The ash content of the diets was in the range of 1.47-1.93% (Table 2). The reference diet showed significantly ($P \leq 0.05$) higher ash content (2.67%) compared to our formulated diets. Within the formulated diets, there were no significant differences ($P \geq 0.05$) in the ash content of diets A and B. Diet C had the highest value of ash content (1.93%) followed by diet B (1.50%) and diet A (1.47%). These values were lower than 2-3% that recommended by Royal Tropical Institute, RTI, (1987) for the ash content of weaning foods. It was also the range of 1.99-5.60% reported by Mohamed (2004). There was a significant difference ($P \leq 0.05$) between the diets in the carbohydrate (CHO) content. The highest value of CHO was given by diet A, which was found to be 67.47% followed by diet B (59.74) and diet C (58.60%). All the diets had lower CHO content compared to that of the reference diet. Diet A had CHO value higher than 61% which recommended by RTI (1987). All the diets had lower CHO value within the range of 47.1-72.0% reported by Mohamed (2004). The fiber content of the formulated diets was found to be in the range of 0.66-1.01%. There was a significant difference ($P \leq 0.05$) between all the diets in fiber content. All the diets had fiber content lower than the level of 2.5% specified by PAG (1975) and were within the range of 0.94-1.25% reported by Asma *et al.* (2006). FAO (1985) reported that the crude fiber content of supplementary food should not exceed 5%, and the fiber content of the diets satisfies this recommendation. In the recent years, dietary fiber has become of considerable interest in human nutrition. Fiber in relation to infant and preschool children raises important nutritional issues, primarily in relation to its potential disadvantages, rather than an advantage (Jansen, 1980). However, emphasis is placed on the importance of keeping low level of fiber in weaning food. Nevertheless, increasing the intake of dietary fiber is known to enhance the stool bulk. Possible undesirable aspects of high level in weaning food include increasing the bulk and lowering the caloric density, irritating to the gut mucosa. They may also affect the efficiency of absorption of various nutrients of significance in diets with marginal nutrients content (Asma *et al.*, 2006). The caloric value of the diets were found to be in the range 306.07-380.59 kcal, which was lower than the value of 406.2-442.6 kcal reported previously (Annan and Palhar, 1995; Asma *et al.*, 2006) but it was higher than 198.19-308.2 kcal reported by Mohamed (2004). FAO/WHO (1998) recommended the foods for feeding infants and children should be energy-dense. FAO/WHO (1998) also stated that is low energy intake foods tend to limit total energy intake and the utilization of other nutrients. It was recommended that a special attention must be paid to the low energy content of many vegetative weaning foods, caused by the low fat and high fiber, as small infants may have difficulty in consuming the necessary volume of diet to achieve an adequate energy intake (Wahed *et al.*, 1994). Estimation of the required energy from complementary foods can be calculated as the difference between the total recommended intake and the energy consumed from breast milk at different ages (Kenneth and Brown, 2000). The estimated energy need from complementary foods is approximately 200 kcal/day for infants aged 6-8 months, 300 kcal/day for infants aged 9-11 months, and 550 kcal/day for children aged 12-23 (FAO, 2001).

Mineral content

The mineral content of the diets was shown in Table 3.

Table 3. *Mineral content (mg/100g) of the diets*

Diet	Mn	Mg	Ca	Zn	Fe	Na	K	P
A	0.90±0.04[a]	69.30±1.11[c]	48.31±1.77[b]	2.30±0.14[d]	14.05±0.99[a]	24.70±0.63[c]	160.23±8.11[b]	397.11±9.99[a]
B	0.70±0.05[b]	93.90±1.38[b]	68.11±2.04[a]	4.84±0.71[b]	10.23±0.75[c]	34.70±0.69[a]	140.15±2.33[c]	157.54±8.04[d]
C	0.67±0.08[c]	97.20±1.54[a]	12.46±1.29[d]	2.53±0.03[c]	5.19±0.87[d]	30.90±0.52[b]	140.02±5.78[c]	260.81±5.23[c]
Reference	0.30±0.01[d]	34.60±0.96[d]	33.77±1.88[c]	5.76±0.65[a]	11.24±0.43[b]	22.00±0.23[d]	320.89±6.74[a]	344.10±7.88[b]

Values are means ± standard deviation of triplicate samples. Means not sharing a common superscript letter in a column are significantly different at $P \leq 0.05$.

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Analysis of variance showed significant differences in the minerals content between all diets. Diet A had the highest contents of Fe, P, Mn among all diets while diet C has the greatest concentration of Mg. The Zn of all formulated diets was in the range of 2.3 to 4.84 mg/100 g that was slightly lower than that of the reference diet. The Ca and Fe content of diet A and B of the blends was within the recommended weaning food standard levels prescribed by the FAO for baby foods (FAO, 2001). Complementary foods are important sources of micronutrients for developing infants. Iron, zinc, phosphorus, magnesium and calcium have been identified as the problem nutrients from six months of age and must be supplemented by the addition of complementary food (Brown *et al.*, 1998).

Essential amino acid content and scores of the diets

Table 4 shows the essential amino acid profile of the formulated diets. All diets acquired lower essential amino acids profile compared to that of the reference diet.

Table 4. *Essential amino acid content (g/100 g) and scores (%) of the diets*

Diets	A	B	C	Reference diet	Reference protein (FAO/WHO,1991) (g/100 g)
Amino acids content (g/100 g)					
Lysine	0.21	0.30	0.48	3.29	5.8
Leucine	2.42	2.96	3.37	6.71	6.6
Isoleucine	1.79	1.96	2.19	4.79	2.8
Therionine	0.49	0.87	1.16	2.87	3.4
Histidine	0.50	0.80	1.02	2.33	1.9
Valine	1.95	2.34	2.60	4.57	3.5
Methionine + Cysteine	0.63	0.78	0.94	2.38	2.5
Phenylalanine +Tyrosine	1.53	2.04	2.47	5.25	6.3
Amino acids scores (%)					
Lysine	3.62	5.17	8.28	26.72	
Leucine	36.67	44.85	51.06	101.52	
Isoleucine	62.86	70.00	78.21	171.07	
Therionine	14.40	25.59	34.12	84.41	
Histidine	26.32	42.11	53.68	122.63	
Valine	55.71	66.86	74.29	130.52	
Methionine + Cysteine	25.20	31.20	37.60	91.60	
Phenylalanine +Tyrosine	24.29	32.38	39.21	83.33	

However, with increasing the amount of sesame flour in the formula the content of each amino acid significantly increased. Consequently, diet C showed the highest values in all essential amino acids followed by diet B and C. The proportional rise in the amino acids values with increasing the sesame flour substitution is logic because legumes protein is known for its complete amino acids profile compared to that of cereal protein that is deficient in some essential amino acids such as lysine and methionine. Interestingly, the content of the most limiting amino acid lysine of the diets were significantly improved and was ranged from 0.21% in diet A to 0.49% in diet C. These values were lower than the range 3.02-4.68 (Asma *et al.*, 2006) reported for some locally made weaning foods. The blending of lysine-deficient wheat with high-lysine legume and skim milk improved the profile of amino acids, in particular, lysine. The chemical score of essential amino acids (Table 4) was calculated according to the reference values reported by FAO/WHO/UNU (1985). Lysine gave the lowest value of chemical score for all of the diets. For all the formulated diets, the lysine score improved concomitantly with increasing the concentration of sesame flour in the diet. Within the formulated diets, the diet C gave the highest values of chemical score for the amino acid compare to other diets. The chemical score of all formulated diets was lower than that of the reference diet. The diets will be prepared by the addition of milk or other nutritious solutions which will increase the chemical score. Sulphur containing amino acids gave lower chemical score when compared with the reference diet. The minimum score for any of the essential amino acid designate the limiting amino acids and provides a rough estimation of the protein quality of the food (Asma *et al.*, 2006). Threonine was the second limiting amino acid in most of the formulated diets, at 14.40% to 34.12%.

Protein digestibility

In vitro protein digestibility is a convenient and rapid way to assay the potential bioavailability of protein by enzymatic digestion under model conditions. The protein digestibility of the diets, as well as the reference diet, is given in Table 5.

Table 5. *In vitro protein digestibility and protein efficiency ratio of the diets*

Diets	*In vitro* protein digestibility (%)	Protein Efficiency Ratio (PER)
A	87.86±0.90[d]	1.14±0.03[a]
B	92.35±1.01[c]	1.08±0.01[b]
C	95.51±0.08[a]	1.05±0.00[d]
Reference diet	94.12±0.01[b]	1.06±0.00[c]

Values are means ± standard deviation of triplicate samples. Means not sharing a common superscript letter in a column are significantly different at $P \le 0.05$.

Among all diets, the highest protein digestibility was found to be (95.51%) for diet C whereas the lowest one was in diet A that gave 87.86%. Analysis of variance revealed a significant difference ($P \le 0.05$) in the protein digestibility in all diets. With increasing the sesame flour, the digestibility of the protein was proportionally ($P \le 0.05$) enhanced. With exception of diet A, the protein digestibility for the diets in the current study was significantly higher than the values 88% and 89% reported for soy based weaning food (Mitchell and Grundel, 1986). Asma *et al.* (2006) reported the protein digestibility in the range of 84.6-92.0 % for weaning blends made from fermented and/or malted sorghum supplemented with legumes and oil seeds flours. All the tested diets acquired higher protein digestibility value than 83.83 reported by Mohamed (2002).

The protein efficiency ratio (PER) of the diets was shown in Table 5. It was ranged from 1.05 to 1.1. Diet A and Diet B had significantly higher PER than the reference diet (1.06); whereas PER for diet C was 1.05 was lower than the reference diet. There was a significant difference ($P \le 0.05$) between all the diets in PER. The calculated PER of the formulated diets and reference diet was lower than the minimum value (2.1) recommended for such foods by the UN Protein Advisory Group (Wondimu and Malleshi, 1996). Previously, PER values in the range of 1.03-1.91 for many sorghum-legumes-oil seeds blends has been reported (Asma *et al.*, 2006).

Functional properties of the diets

Functional properties denote those physicochemical properties of food proteins that determine their behavior in food during processing, storage, and consumption. The results on the functional properties of the diets are presented in Table 6.

Table 6. *Functional properties of the diets*

Diets	Bulk density (g/cm^3)	Water holding capacity (H_2O ml/100g)	Viscosity (centipoise)	
			Cold paste	Hot paste
A	0.64±0.03[a]	483.33±8.76[a]	500±3.87[b]	550±9.11[b]
B	0.58±0.01[b]	350.00±4.33[b]	350±2.19[c]	400±3.66[c]
C	0.56±0.00[c]	333.33±6.09[c]	600±1.55[a]	650±8.43[a]
Reference diet	0.44±0.06[d]	233.33±2.12[d]	250±4.01[d]	130±5.15[d]

Values are means ± standard deviation of triplicate samples. Means not sharing a common superscript letter in a column are significantly different at $P \le 0.05$.

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The highest bulk density was found in diet A (0.64 g/cm^3) followed by 0.58, 0.56, and 0.44 g/cm^3 for diets B, C, and the reference diet, respectively. Comparing these findings with previous studies, it was found that diet B and C bulk density were lower than 0.6 g/cm^3 reported by Mohamed (2002). All the diets bulk density was within the range of 0.54-0.65 g/cm^3 reported by Asma *et al.* (2004). The bulk densities for the formulated diets were higher than that of reference diet. There were significant differences ($P \leq 0.05$) in bulk density between all diets. Interestingly, the bulk density was concurrently decreased ($P \leq 0.05$) with the increase in the sesame flour supplementation. Higher bulk density is desirable as it helps to reduce the paste thickness which is a significant factor in convalescent and child feeding (Padmashree *et al.*, 1987). High bulk density of powdered food is desirable for packing because it allows more weight to be contained in a limited volume (Asma *et al.*, 2006). Results on the water holding capacity of the formulated diets are depicted in Table 6.

Table 7. *Microbial evaluation of the diets*

Diets	Total bacterial account	Total yeast and molds	*Staphylococcus aureus*	Coliform bacteria	*Salmonella* spp
A	$<10^2$	$<10^2$	$<10^2$	-ve	-ve
B	$<10^2$	$<10^2$	$<10^2$	-ve	-ve
C	$<10^2$	$<10^2$	$<10^2$	-ve	-ve
Reference diet	$<10^2$	$<10^2$	$<10^2$	-ve	-ve

Diet A gave the highest water holding capacity (483.33 ml H_2O/100g), followed by diet B, C, and the control which were 350, 333.33, and 233.33 ml H_2O/100g, respectively. Analysis of variance demonstrated significant differences ($P \leq 0.05$) in water holding capacity between all the diets. The discoveries of the current study were comparable to those reported previously (Mohamed, 2002; Asma *et al.*, 2006).

Similar to the bulk density, the water holding capacity was concurrently decreased ($P \leq 0.05$) with the increase in the sesame flour supplementation. Hydration or rehydration is the first and maybe most critical step in imparting desirable functional properties to proteins in a food system. Intrinsic factors are affecting water binding properties of food flours with relatively high protein contents include amino acid composition, protein conformation, and surface polarity / hydrophobicity (Barbut, 1999).

The difference in protein structure and the presence of different hydrophilic carbohydrates might be responsible for variation in the water holding capacity of the diets. Diets flour with high water holding capacity has more hydrophilic constituents such as polysaccharides. Results in the viscosities of hot and cold slurries of all diets are shown in Table 6.

Diet C acquired the highest viscosity of both cold and hot paste (600 and 650 cp) followed by diet A (500 and 550 cp) and diet B (350 and 400 cp) and finally the reference diet (250 and 130 cp).There was a significant difference ($P \leq 0.05$) in the viscosity between all diets. All the diets in the current study had acquired relatively lower viscosity than the range of 538-2893 cp in cold paste and 526-2876 in hot paste reported by (Asma *et al.*, 2006). Viscosity of food is one of the important determinants of food acceptability to both mothers and young children (Ikujenlola, 2008). Little hot diet viscosity is a desirable characteristic in weaning food known to facilitate chewing and swallowing (Waterlow and Payne, 1975). In addition, weaning foods must have an easy to swallow, semi-liquid consistency 1000 to 3000 cp. (Nout, 1990).

Microbial evaluation

The results on the microbial load in the formulated diets are presented in table 7. The result revealed that all the diets are free from *Staphylococcus aureus*, *Salmonella* spp. and *coliform* bacteria. The total number of bacteria, yeast, and molds are little ($<10^2$).

Our results are comparable to those of Asma *et al.* (2006), who reported a lower plate count of weaning diets. Being free from pathogenic bacteria these formulas are considered to be safe.

Sensory quality of the diets

Results on the mean scores for the sensory attributes of the diets are shown in Table 8.

Table 8. *Sensory quality of the diets*

Diets	Color	Flavor	Consistency	Taste	Over all acceptability
A	45.22±0.77[c]	47.98±0.63[c]	51.89±0.57[b]	46.12±0.83[c]	47.11±0.12[c]
B	52.34±0.13[b]	59.11±0.98[b]	52.11±0.40[b]	59.63±0.78[b]	54.45±0.88[b]
C	59.01±0.54[a]	67.50±0.44[a]	66.00±0.93[a]	66.22±1.08[a]	73.61±1.55[a]
Reference diet	24.56±0.22[d]	19.34±0.17[d]	20.00±0.52[c]	19.69±0.66[d]	19.21±0.09[d]

Values are means ± standard deviation of triplicate samples. Means not sharing a common superscript letter in a column are significantly different at $P \leq 0.05$.

Generally, with increasing the sesame flour substitution the scores of all sensory attributes were significantly ($P \leq 0.05$) increased. The reference diet showed the lowest values for all the sensory attributes whereas the diet C showed the highest scores. Although there were significant differences ($P \leq 0.05$) in the color between all diets, diet A was closely resembled the reference diet in term of color compared to that of other diets (Fig 1).

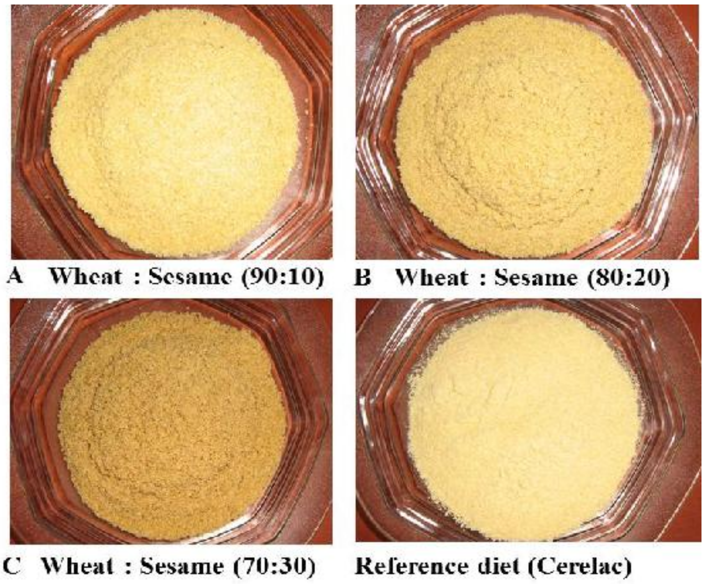

Figure 1. *The differences in the appearance of the diets.*

Unexpectedly, the assessor preferred the diet C compared to other diets including the commercial diet. This could result from the fact that the entire assessors were adults, and the reference diet were Cerelac, which was prepared only for infants and children. Thus, the formulated diets gain higher scores than Cerelac. Moreover, the assessors preferred great sesame substituted diet because people in Sudan and many other African countries like to consume the sesame containing foods.

Conclusions

Defatted sesame flour can actually be used in wheat-based weaning diets as an acceptable protein and mineral supplement. Wheat and sesame flour formulations developed in this study successfully produced weaning diets high in protein and energy with acceptable functional and sensory characteristics, as well as excellent nutritional quality. Therefore, we strongly recommend further study to determine the feasibility of producing the diets commercially at a large scale.

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