Nutritional, In-vitro Digestibility and Organoleptic Properties of Homemade Complementary Foods Formulated from Pearl Millet [Pennisetum glaucum], Sweet Potato [Ipomoea batatas] and Watermelon [*Citrullus lanatus*] Seed Flour Blends

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ABSTRACT

Background: *Traditional infant diet is characterized with low protein-energy density, hence, predisposes children to high morbidity and mortality. This study was aimed to develop high protein-energy density complementary foods from local food materials.*

Methods: *Pearl millet grains (P), sweet potato tubers (S) (sliced into chips and blanched), and watermelon seeds (W) were washed with distilled water, drained, oven dried, and milled into fine flour. These flour samples were blended to obtain PSW10 [65:25:10], PSW20 [60:20:20], PSW30 [55:15:30], and PSW40 [50:10:40]; while PSF [70% pear millet & 30% Sweet potato] and commercial formula were the control samples. Chemical composition, functional properties, protein/starch digestibility, sensory attributes were evaluated using standard methods. Data were analysed using Statistical software package. Data were expressed as means (±SD), and means were separated by the New Duncan Multiple Range Test at P<0.05.*

Results: *Protein and energy value of the complementary foods ranged from 7.87 to 16.57 g/100g and 399.41 to 417.58 kCal/100g, respectively. Essential minerals like calcium, phosphorous, iron, and zinc were present in appreciable amount, while Ca/P and Na/K ratios were within the recommended values. In-vitro starch and protein digestibility values ranged from 59.51 to 73.57% and 71.03 to 81.29, respectively. Phytochemical in the samples were within tolerable levels. For overall acceptability, PSW30 [55% pear millet, 15% sweet potato, 30% watermelon seed] was rated highest among experimental samples, but insignificantly [p<0.05] lower than the control samples.*

Conclusion: *The study established that PSW40exhibited best nutritional quality, and therefore suitable as a good substitute for low protein-energy dense local complementary foods.*

Keywords: Homemade complementary foods, Nutritional properties, Protein/starch digestibility.
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INTRODUCTION

Deficiency of energy and essential nutrients during the complementary feeding period has been implicated as the main causes of acute malnutrition, morbidity and mortality in children [1]. In Nigeria and other developing countries, commercially available complementary foods are too costly for the average family, and this makes nursing mothers to depend on low quality traditional complementary foods [2] with serious nutritional and health consequences on the infants [1].

Pearl millet contains appreciable amount of protein and essential micronutrients, and it is cultivated in many developing countries [3, 4, 5]. Sweet potato is high in soluble carbohydrates, minerals and vitamins, and plays an important role in improving food security in Africa [2]. Sweet potato offers an excellent alternative to cereal-based complementary foods in reducing the incidence of malnutrition among children [6]. Watermelon is a tropical fruit crop, which contains essential nutrients like protein and micronutrients [7, 8, 9].

MATERIALS AND METHODS

Sources of Materials and Sample Preparations

Pearl millet kernels, sweet potato tubers, watermelon seeds and commercial infant formula were purchased from Erekesan market, Akure. The pearl millet flour was prepared using the method described by Akinola et al. [10], sweet potato flour was prepared using Kaur and Sandhu method [11], and watermelon seed flour was prepared according to the method of Owheruo et al. [12]. The flour samples were blended as follows: PSF (70% pear millet kernels, 30% Sweet potato tuber), PSW10 (65% Pearl millet kernels, 25% sweet potato tuber, 10% watermelon seeds), PSW20 (60% Pearl millet kernels, 20% sweet potato tuber, 20% watermelon seeds), PSW30 (55% Pearl millet kernels, 15% sweet potato tuber, 30% watermelon seeds), PSW40 (50% Pearl millet kernels, 10% sweet potato tuber, 40% watermelon seeds) and commercial formula (control). The proportion of each flour samples in the formulations was determined using material balance equations to give >18 g protein/100g food recommended for infant foods [13].

Determination of Chemical Composition and Functional Properties of Complementary Foods

Proximate Compositions: The proximate composition of the formulated complementary foods, and controls were analyzed using standard methods [14]. Moisture content was determined by the drying method using hot-air oven circulation. Ash content was determined through incineration (550 °C) using a muffle furnace. Crude protein was determined by micro-Kjeldahl, and calculated by multiplying the corresponding total nitrogen content by a factor of 6.25. Crude fat content was determined by a Soxhlet extractor. Crude fiber was determined by the following method of AOAC [14]. Available carbohydrate was calculated by difference, while energy value was calculated using Atwater's calorie conversion factors of 4 kcal/g for crude protein, 9kcal/g for crude fat, and 4kcal/g for available carbohydrate [14].

Mineral Composition: The minerals [i.e., Ca, Mg, Fe, Cu, Zn, Mn & Pb] in the food samples were determined using Atomic Absorption Spectrophotometer [AAS Model SP9]. Sodium and potassium were determined using flame emission photometer [Sherwood Flame Photometer 410, Sherwood Scientific Ltd. Cambridge, UK] with NaCl and KCl as the standards [14]. Phosphorus was determined using Vanodo-molybdate method [14]. The Na/K and Ca/P, molar ratios were calculated (Ferguson et al., 15].

Functional Properties: The functional properties of the flour samples were determined as follows: least gelation by the method of Coffman and Garcia, [16], water/oil absorption capacities and bulk density by the methods of Omueti et al. [17], and swelling capacity by the method of El-Gindy [18].

Determination of In-vitro Protein and Starch Digestibility

In-vitro protein digestibility of each sample was determined using the enzymatic method described by Kanu et al. [19]. Five grams of each of the formulated samples were weighed into 5 ml centrifuge tubes and 15 ml of 0.1 M HCl containing 1.5 mg pepsin-pancreatin added. The tubes were incubated at 37ºC for 3 h. The suspension was then neutralized with a phosphate buffer [pH 8.0] containing 0.005 M sodium oxide. Exactly 1 ml of toluene was added to prevent microbial growth, and the mixture was repeatedly shaken gently and incubated for 24 h at 37 ºC. After incubation, samples were treated with 10 ml of 10% trichloroacetic acid [TCA] and centrifuged at 5000 rpm for 20 minutes at room temperature. The TCA soluble fraction in the supernatant liquid was assayed for nitrogen using the micro-Kjedahl method. The percentage of protein digestibility was calculated using the formula;

$$\text{Protein digestibility [\%]} = \frac{\text{Nitrogen in the supernatant - Nitrogen in the black X 100}}{\text{Nitrogen in the sample}}$$

In-vitro starch digestibility was determined using the Method of Singh et al. [20]. Exactly 50 mg each of the food samples were weighed into test tubes and mixed with 1 ml of 0.2 M phosphate buffer (pH 6.9). Pancreatic α-amylase [0.5 ml; 20 mg enzyme dissolved in 50 ml of the same buffer] was added to the sample mixtures and incubated at 37ºC for 2 h. After incubation, 2 ml of 3,5-DNS reagent (prepared by dissolving 200 mg crystalline phenol, 1 g of 3,5-dinitrosalycyclic acid and 50 mg sodium sulphite in 1% NaOH solution) was added immediately. The mixture was heated for 5-15 min in a boiling water bath. Exactly 1 ml of K-Na Tartarate solution was added to the mixture test tubes and allowed to cool at 25 ºC. The solution was therefore made up to 25 ml with distilled water and filtered prior to reading of the absorbance at 550 nm. A blank was run simultaneously. A standard curve was prepared using maltose and values obtained were expressed as mg maltose equivalent per 100 mg of sample.

Phytochemical composition of the Complementary Foods

The phytochemicals compositions of the complementary foods were determined as follows: Phytate content was determined as described in Ayele et al. [21], while flavonoids and saponin by the methods of Krishnaiah et al. [22]. Tannin content by the modified vanillin-hydrochloric acid method [23]. Total phenolic content was spectrophotometrically determined by Folin Ciocalteu reagent assay using garlic acid as standard [24].

Sensory Attributes Evaluation

The sensory attributes of formulated diets and control samples were evaluated as reported by Forsido et al. [25]. Each of the experimental foods [50 g] was mixed with boiled water (250 ml, 100 0C, 15 min) to make slurry, and served warm to twenty [20] semi-trained panellists (Nursing mothers/caregivers). The Panellists assessed the samples based on appearance, aroma, taste, consistency and overall acceptability using 9-point Hedonic scale from dislike extremely [1] to like extremely [9].

Statistical Analysis

Data were analysed in triplicate, and means were subjected to One-Way Analysis of Variance [ANOVA] using Statistical Package for Social Sciences [SPSS] version 20.0. The means were separated using New Duncan's Multiple Range Test at 95% confidence level [$P<0.05$].

RESULTS

Chemical Compositions and Energy value of Complementary foods

The proximate composition (g/100g) and energy value (kCal./100g) of complementary foods is shown in Table 1. Moisture, crude protein, crude fiber and energy value of the complementary foods ranged from 9.16 to 9.51, 7.87 to 16.57, 4.68 to 9.72, and 399.41 to 417.58, respectively. The findings showed that crude protein and fiber content of the experimental food products significantly ($p<0.05$) increased as the amount of watermelon seed flour incorporated increases. The mineral composition (mg/100g) of the complementary food samples shows that potassium, sodium, iron, zinc and calcium contents ranged from 6.53 to 8.26, 5.09 to 5.89, 12.29 to 12.85, 11.99 to 12.94 and 8.10 to 9.03, respectively, and the concentrations were significantly ($p<0.05$) increased as the inclusion of watermelon seed flour increase. Sodium/potassium (Na/k) and Calcium/phosphorus (Ca/P) molar ratios ranged from 0.71 to 0.82 and 1.19 to 1.25, respectively.

Table 1: Proximate (g/100g), Energy (kcal/100g) and Mineral Composition of Complementary Foods

	PSF	PSW_{10}	PSW_{20}	PSW_{30}	PSW_{40}	Control	*Ref.
Moisture	$10.01±0.03^a$	$9.16±0.03^f$	$9.27±0.02^e$	$9.33±0.04^d$	$9.51±0.04^c$	$9.94±0.02^b$	<10
Ash	$1.62±0.01^d$	$1.09±0.02^f$	$2.83±0.01^c$	$3.18±0.01^b$	$3.43±0.01^a$	$1.49±0.01^e$	<3
Fat	$15.22±0.02^d$	$15.46±0.02^d$	$16.66±0.09^c$	$17.62±0.04^b$	$18.01±0.04^a$	$11.95±0.02^e$	10-25
Fibre	$1.53±0.02^e$	$4.68±0.03^d$	$5.55±0.01^c$	$6.30±0.03^b$	$9.72±0.03^a$	$1.43±0.01^f$	<5
Protein	$6.12±0.01^f$	$7.87±0.01^e$	$13.13±0.17^c$	$15.36±0.10^b$	$16.57±0.08^a$	$11.55±0.17^d$	>14
Carb.	$65.50±0.07^a$	$61.74±0.05^c$	$52.56±0.18^d$	$48.21±0.17^e$	$42.76±0.17^f$	$63.64±0.19^b$	64
Energy	$423.46±3.01^a$	$417.58±1.78^b$	$412.70±0.11^c$	$412.86±0.09^c$	$399.41±0.32^e$	$408.33±1.15^d$	344
Minerals							
Ca	$7.89±0.01^e$	$8.10±0.01^d$	$8.16±0.01^c$	$8.71±0.02^b$	$9.03±0.01^a$	$7.39±0.01^f$	250
Mg	$5.13±0.02^d$	$5.84±0.01^d$	$5.99±0.01^c$	$6.27±0.01^b$	$6.50±0.01^a$	$6.39±0.01^e$	76
P	$6.88±0.01^e$	$6.78±0.01^d$	$6.83±0.01^c$	$6.93±0.03^b$	$7.01±0.01^a$	$6.10±0.02^f$	356
K	$7.45±0.01^f$	$6.53±0.01^d$	$6.71±0.01^c$	$6.89±0.01^b$	$8.26±0.01^a$	$7.66±0.01^e$	516
Na	$5.59±0.00^c$	$5.09±0.01^e$	$5.38±0.01^d$	$5.62±0.01^b$	$5.89±0.01^a$	$4.63±0.00^f$	296
Fe	$12.58±0.00^c$	$12.29±0.01^e$	$12.47±0.01^d$	$12.64±0.02^b$	$12.85±0.02^a$	$10.23±0.01^f$	16
Zn	$10.84±0.00^e$	$11.99±0.02^d$	$12.35±0.01^c$	$12.67±0.01^b$	$12.94±0.01^a$	$12.66±0.01^b$	3.20
Cu	$0.03±0.01^b$	$0.02±0.01^b$	$0.01±0.00^b$	$0.01±0.00^c$	$0.01±0.00^c$	$0.04±0.01^a$	0.89
Mn	$2.99±0.02^f$	$3.14±0.02^e$	$3.51±0.01^c$	$3.72±0.01^b$	$4.22±0.01^a$	$3.41±0.01^d$	1.50
Pb	$0.00±0.00^a$	$0.00±0.00^a$	$0.00±0.00^a$	$0.00±0.00^a$	$0.00±0.00^a$	$0.00±0.00^a$	0.01
Na/K	0.75^d	0.78^c	0.80^b	0.82^a	0.71^e	0.60^f	<1.00
Ca/P	1.15^e	1.19^d	1.19^d	1.25^b	1.28^a	1.21^c	>0.5

Means (±SEM) with different alphabetical superscripts in the same row are significantly different at P<0.05

* Ref (30).

Phytochemical composition (mg/g) of the formulated complementary food samples is presented in Table 2. The content of the phytochemicals (mg/g) in experimental complementary foods were alkaloid (10.99 to 18.67), flavonoid (41.95 to 69.09), tannin (10.08 to 13.50), saponin (6.95 to 7.84), oxalate (3.44 to 4.91) and phytate (7.00 to 8.55), and were significantly ($p<0.05$) decreased with increasing amount of watermelon seed flour inclusion

In-vitro Protein and starch digestibility of Complementary Foods

In-vitro starch digestibility of the complementary foods presented in Figure 1 varied from 59.51 to 73.57% PSW10 and PSW40, respectively, and these values were significantly ($p<0.05$) higher in formulated diets than PSF (55.59%), but comparable to commercial food sample (70.875%). Similarly, the in-vitro protein digestibility of formulated complementary foods ranged from 71.03 to 81.29%, and these values were significantly ($p<0.05$) higher than in PSF (69.38%), but within the value of commercial formula (71.33%).

Table 2: Phytochemical composition (mg/g) of the formulated complementary food samples

Parameters	PSF	PSW_{10}	PSW_{20}	PSW_{30}	PSW_{40}	Control
Alkaloid	22.10 ± 0.05^{a}	18.67 ± 0.03^{b}	15.09 ± 0.05^{d}	12.98 ± 0.02^{e}	10.99 ± 0.05^{f}	17.37 ± 0.06^{c}
Flavonoid	30.87 ± 0.07^{f}	41.95 ± 0.03^{e}	48.69 ± 0.03^{d}	59.76 ± 0.05^{c}	69.09 ± 0.07^{a}	61.00 ± 0.09^{b}
Tannin	16.74 ± 0.03^{a}	13.50 ± 0.09^{c}	13.00 ± 0.05^{d}	11.94 ± 0.03^{e}	10.08 ± 0.04^{f}	15.09 ± 0.06^{b}
Saponin	9.56 ± 0.03^{a}	7.84 ± 0.05^{b}	7.61 ± 0.04^{c}	7.20 ± 0.04^{d}	6.95 ± 0.03^{e}	7.80 ± 0.07^{b}
Oxalate	5.84 ± 0.02^{a}	4.91 ± 0.09^{b}	4.30 ± 0.07^{c}	3.92 ± 0.05^{d}	3.44 ± 0.09^{e}	5.53 ± 0.16^{ab}
Phytate	9.00 ± 0.03^{a}	8.55 ± 0.06^{b}	8.20 ± 0.05^{c}	7.39 ± 0.03^{d}	7.00 ± 0.02^{e}	8.44 ± 0.09^{b}

Means (±SEM) with different alphabetical superscripts in the same row are significantly different at P<0.05

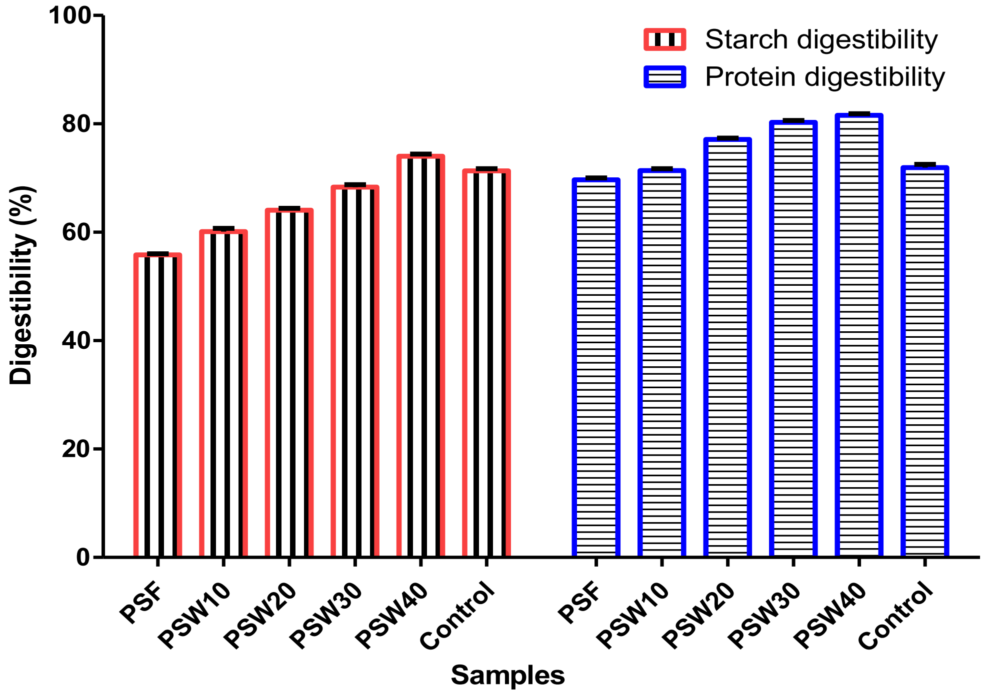

Figure 1: Starch and protein digestibility of complementary foods

Functional Properties of Formulated Complementary Food

Table 3 shows the functional properties of the flour blends. The bulk density and water absorption capacity of the flour samples reduced significantly (P<0.05) as the percentage of watermelon seed flour increased from 10% to 40% with values ranging from 0.68-0.80 g/ml and 13.40-13.85 g/ml, respectively. Whereas, swelling capacity (76.39 to 89.97%) increased significantly (p<0.05) as the percentage of watermelon seed flour inclusion increased. For the least gelation capacity, experimental complementary foods had the highest value (8%), except in PSW40, compared to PSF and control sample.

Sensory Attributes of Complementary Food Samples

The sensory attributes of the formulated complementary foods are presented in Table 4. The results showed that, flavour, texture and taste of the samples were not significantly different

Table 3: Functional Properties of the flour blends for the formulation of complementary foods

Parameters	PSF	PSW_{10}	PSW_{20}	PSW_{30}	PSW_{40}	Control
BD (g/ml)	0.85 ± 0.06^{a}	0.80 ± 0.03^{ab}	0.77 ± 0.07^{bc}	0.73 ± 0.03^{c}	0.68 ± 0.05^{c}	0.81 ± 0.03^{ab}
WAC (g/ml)	14.88 ± 0.04^{a}	13.85 ± 0.05^{b}	13.76 ± 0.08^{c}	13.58 ± 0.04^{d}	13.40 ± 0.02^{e}	13.79 ± 0.08^{c}
SC (%)	75.85 ± 0.09^{d}	76.39 ± 0.04^{d}	79.53 ± 0.08^{c}	86.11 ± 0.09^{b}	89.97 ± 0.05^{a}	65.79 ± 0.08^{e}
	7.00 ± 0.00^{b}	8.00 ± 0.00^{a}	8.00 ± 0.00^{a}	8.00 ± 0.00^{a}	7.00 ± 0.00^{b}	7.00 ± 0.00^{b}

Means (±SEM) with different alphabetical superscripts in the same row are significantly different at P<0.05 (BD: Bulk Density; WAC: Water absorption capacity; SC: Swelling capacity; LGC: Least gelation capacity).

Table 4: The Sensory Attributes of Complementary Foods

Sample	**PSF**	**PSW_{10}**	**PSW_{20}**	**PSW_{30}**	**PSW_{40}**	**Control**
Colour	$7.15^{a}\pm1.81$	$6.75^{b}\pm2.07$	$5.80^{c}\pm1.77$	$6.05^{bc}\pm2.16$	$5.90^{c}\pm2.32$	$7.15^{a}\pm1.84$
Appearance	$7.00^{a}\pm1.56$	$6.50^{a}\pm2.09$	$6.10^{a}\pm2.29$	$6.25^{a}\pm1.80$	$6.60^{a}\pm2.30$	$7.00^{a}\pm1.72$
Flavour	$6.20^{bc}\pm0.69$	$6.05^{bc}\pm1.70$	$5.35^{c}\pm2.11$	$5.70^{bc}\pm2.20$	$6.85^{ab}\pm1.69$	$7.75^{a}\pm1.21$
Texture	$6.55^{ab}\pm1.49$	$5.90^{b}\pm2.05$	$6.70^{ab}\pm1.26$	$6.20^{ab}\pm1.70$	$6.05^{ab}\pm1.70$	$7.05^{a}\pm1.19$
Taste	$6.00^{ab}\pm2.53$	$5.25^{b}\pm2.95$	$5.15^{b}\pm1.81$	$5.80^{ab}\pm2.04$	$5.80^{ab}\pm2.26$	$7.30^{a}\pm1.81$
Acceptability	$7.05^{ab}\pm1.47$	$6.45^{b}\pm1.66$	$6.80^{ab}\pm 1.01$	$6.85^{ab}\pm1.46$	$6.45^{b}\pm1.73$	$7.70^{a}\pm1.08$

Means (±SEM) with different alphabetical superscripts in the same row are significantly different at P<0.05

(p>0.05) from PSF sample, however, there was insignificant (p>0.05) different between the formulated samples and that of commercial formula. For the overall acceptability, sample PSF and commercial formula (control) were rated higher, however, there was no significant (p>0.05) difference when compared with other experimental food samples.

DISCUSSION

Adequate nutrition during infancy is essential to ensure optimal growth, health, and development of children to their full potential. Hence, homemade nutrient-dense infant diets are recommended to prevent risk of illness, and mortality among weaning-aged children. In this study, the formulated complementary foods contain appreciable amount of protein and energy density compared to PSF sample and commercial formula. Interestingly, the protein and energy content of these formulated diets, particularly PSW40, may be suitable to provide above 80% (per 100g sample) of daily requirement of the infants. However, the nutrient composition of formulated infant diets in this study is comparably similar to that of Ijarotimi [27] report for complementary foods developed from maize, defatted groundnut and ginger. This similarity may be due to the raw materials [legumes & cereals] and processing methods involved.

The formulated diet contains appreciable amount of iron, zinc, calcium and phosphorous; and these essential minerals play major roles in child growth and development. Evidence has shown that calcium and phosphorous are important for bone and teeth formation, while iron and zinc are essential for brain development and blood formation [28]. Adequate intake of iron, zinc, phosphorous, magnesium and calcium may prevent iron-deficiency anaemia, bone deformation and low immunity [28]. However, these minerals (iron, zinc, phosphorus, magnesium, and calcium) have been identified as the major deficiencies among children (6 months), and must be supplemented with the addition of complementary food [29].

The Na/K and Ca/P molar ratios of the food samples are in line with the recommended value of <1 and >1 [30], respectively. Studies have also shown that food should be considered as good if Ca/P ratio is >1 and poor if this ratio is <0.5 [31], and that Ca/P molar ratio greater than 0.5 may facilitate bone and teeth formation. In the same vein, food with Na/K molar ratio less than one [<1] may be considered ideal food particularly for children with immature heart [31].

Digestibility of protein is an important criterion for evaluation of food quality as well as an indicator for protein bioavailability in foods. The in-vitro protein digestibility of the complementary foods of this study was significantly [P≤0.05] different from each other and increases with the increase in the level of watermelon flour substitutions. The results showed that PSW40 exhibited highest protein digestibility, and this finding could be attributed to the low antinutrient factors like tannin, oxalate and phytate, which may chelate with the protein that present in the food sample, and thereby inhibiting the activity of proteolytic enzymes to breakdown protein into smaller molecular units (amino acids). According to Almeida et al. [32], a protein with high digestibility is potentially of a better nutritional value than the one of low digestibility, because it enhances bioavailability of essential amino acids on proteolysis, thus reflecting the protein efficiency. Comparatively, the in-vitro protein digestibility observed in this study is in close range with the recommended values [70%] for ideal foods, and that of Hooda and Jood [33] report for wheat-fenugreek biscuits [37.2 to 70.8 %].

The digestion of carbohydrate depends on various factors such as amylose to amylopectin ratio, and interaction with other nutrients like fiber, protein and fat, which may inhibit the activities of carbohydrate hydrolyzing enzymes [34]. The in-vitro starch digestibility of the formulated complementary foods ranged from 59.5% to 73.6%for PSW10 and PSW40, respectively, and the values were significantly [p<0.05] higher than PSF [55.6%], but similar to commercial formula [70.9%]. The starch digestibility of experimental complementary foods in this study is comparatively lower than what obtained for cereal-based breakfast meal (78.16 to 88.65%) reported by Edima-Nyah et al. [35]. This variation could be attributed to food compositions, and interaction between nutrients like protein and starch. This finding agrees with the report that starch digestibility is influenced by several factors such as chemical nature of the starch, presence of other nutrients like protein, fat and fibers, complexes formed with other nutrients, and the matrix of the food that is achieved by processing, which can be favourable or non-favourable [36]. It is evident that soluble dietary fiber alters physico-chemical properties of starch digestion by increasing the viscosity, which results in reduced interactions between starch and alpha amylase because of limited access to the substrate. Besides, insoluble fiber is known to inhibit enzyme activity by non-specific binding resulting in decreased nutrient bio-accessibility [37].

Phytochemicals in the formulated diets decreased in concentration, except flavonoid, as the percentage of watermelon seed flour inclusion increase. This finding could be attributed to low phytochemicals in watermelon seed [38]. Interestingly, the phytochemicals in these diets were lower than in PSF, commercial formula, and were within the tolerate levels [39]. Research findings have established that excessive antinutrients like phytate, tannin and oxalate in the diet will form insoluble complexes with divalent minerals like copper, zinc, calcium and iron [40]. This result in a deficit in the absorption of these dietary minerals [40], hence, leads to mineral deficiencies. Flavonoids and saponin are important phytochemicals with antioxidant activity, anticancer, anti-inflammatory, antiviral properties, and cardio-protective effects [41].

The Bulk density of complementary foods was significantly lower [P<0.05] than commercial control and PSF sample. This means that the complementary foods would be an advantage in the preparation of complementary foods [27]. Previous study revealed that bulk density is usually influenced by the particle sizes and density of the flour, and it is very essential in determining the packaging requirement and material handling [27]. Also, study has affirmed that low bulk density is desirable for infants' diets, because high bulk density complementary food limits the caloric and nutrient intake per meal of infant, and that young children are sometimes unable to consume enough to meet their energy and nutrient requirements [27]. Therefore, low-bulk density would enhance energy-nutrient density of a complementary food and economical food packaging [27]. Similar trend was observed for the water absorption capacity of the formulated complementary. The low water absorption capacity is desirable for the food because it may reduce the microbial activity in food product, hence, increasing the shelf life of the food products. Also, Akinsola et al. [42] reported that low water absorption capacity is desirable for making thinner gruels with high caloric density per unit volume. The study indicated that PSW40 had the lowest water absorption capacity, and this finding agreed with the study of Akinsola et al. [42]. For the swelling and least gelation capacities, the formulated complementary foods were significantly higher (P<0.05) than PSF and commercial formula. This finding agrees with the previous studies by Ijarotimi [28], who reported low functional properties for complementary foods formulated from maize, defatted groundnut and ginger.

The organoleptic property of formulated complementary foods is presented in Table 6. The appearance, aroma, texture, taste and overall acceptability of experimental complementary foods were significantly ($p<0.05$) rated below control samples The variation between the rating of sensory attributes of experimental complementary foods and that of control samples could be attributed to the familiarity of the panellists to the control samples or variation in food compositions; whereas, among the experimental complementary foods, PSW30 was the most preferred in overall acceptability. This finding could be ascribed to differences in food compositions such as pearl millet, sweet potato and watermelon, which might have influenced sensorial attributes of the formulated food products compare to that of control sample. Interestingly, to some of the sensory attributes there were no significant ($p>0.05$) different between the experimental food samples and that of the control samples. This finding further established nutritional quality and acceptability of the experimental food products as a potential complementary food.

CONCLUSION

The present study established that PSW40 (50% Pearl millet kernels, 10% sweet potato tuber, 40% watermelon seeds] has the highest protein and energy density. The formulations met the recommended daily intakes of protein for breastfeeding infants (6 - 8 months). Hence, this food sample may be suitable as complementary food and as a substitute for local complementary food in terms of nutrient density.

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