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Physicochemical, Functional and Pasting properties of Orange-Flesh Sweet Potato Starch, Soya bean and Groundnut Flour Complementary Food

Eke-Ejiofor J., Obinna-Echem P.C.*, Wordu G.O., Vito M.B.

Food Science and Technology, Rivers State University, Nkpolu-Oroworukwo, P.M.B 5080. Port Harcourt, Rivers State, Nigeria
*Corresponding author: patience.obinna-echem@ust.edu.ng

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Abstract Complementary food from blends of orange flesh sweet potatoes (*Ipomea batata*) (OFSP) starch, soybean (*Glycine max*) and groundnut (*Arachis hypogea*) flour was formulated and evaluated for physicochemical, functional and pasting properties. The blends of OFSP starch, soybean and groundnut flour were in the ratios of (OFSP:SB:GN): 90:5:5, 85:10:5, 80:15:5, 75:20:5, 70:25:5, 65:30:5, 60:35:5, 55:40:5, 50:45:5 for PSB1 – PSB9, while 100 % OFSP served as control. Standard analytical methods were used for all analysis. pH (4.60 – 5.69), sugar (0.71 - 3.63 %) and amylopectin (70.28 - 85.34 %) increased significantly ($P \leq 0.05$) while starch (69.09 - 87.53 %) and amylose (29.97 - 14.65) decreased with increase in soybean flour addition. Carotenoid content (11.08 – 44.60 mg/kg) will meet >200% of recommended Vitamin A requirement for infants. Bulk density, water absorption capacity, swelling power, solubility index and dispersibility ranged respectively from 0.71 - 0.83 g/ml, 0.59 - 1.35, 9.12 - 14.48, 5.57 - 9.45 and 76.00 – 80.00 %. The peak, trough, breakdown, final and setback viscosities varied significantly ($P \leq 0.05$) from 127.5 - 7291.0, 95.3 - 4332.0, 32.3 - 2959.0, 129.0 -6159.0 and 33.79 - 1827.0 RVU respectively. Increase in pH and sugar, decrease in starch, bulk density and reduction in viscosities of the complementary food with increase in soybean flour addition is very important in achieving a near neutral and high nutrient dense gruel yet thin enough for infant feeding.

Keywords: *orange-flesh sweet potato, soybean, groundnut, complementary food, physicochemical, functional and pasting properties*

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1. Introduction

Complementary foods are formulated food mixtures meant to be fed along with breast milk for infants from 6 months until completely weaned off breast milk [1]. In Nigeria infant complementary food consisting mainly of un-supplemented cereal gruel or pap made from maize, sorghum and or millet are grossly inadequate in some macro-and micronutrients [2]. Complementary foods could be in forms of doughs, porridges, beverages or stiff gels [3]. Starchy foods on cooking form a highly viscous porridge that requires dilution with large volumes of water for effective infant feeding [4]. Such dilutions result in reduction in the already insufficient, energy and chemical composition of the food. Insufficient energy density of complementary foods has been recognized as an etiological factor of protein-energy malnutrition in young children [5]. In developing countries, vitamin A deficiency is widespread in young children [6] and is a leading cause of early childhood death [7].

Sweet potato has been identified as a viable product for use in complementary foods to supplement the nutritional needs of infants in developing countries and at the same time enhancing the utilization of the crop. The orange flesh variety is high in β-carotene content which is a precursor of vitamin A [8]. *β*-carotene is essential for the growth and development of young children. In Sub Sahara Africa where vitamin A deficiency continues to be a problem, development of a complementary food with high content of *β*-carotene is essential. Dietary sources of vitamin A are key to eradicating vitamin A deficiency in Africa as a whole [9]. Orange fleshed- sweet potato is a root crop bio-fortified with *β*-carotene. Foods rich in beta carotene such as the orange-fleshed sweet potato (OFSP) provide sufficient dietary vitamin A [6]. However, infant diets in low income countries consist largely of starchy staples such as maize, millet and sorghum and lack the vitamins and minerals needed for good health and development [10]. Lack of vitamin A during these critical growth periods contribute to growth-stunting during the first 2 years of life, with potential adverse consequences for child development and later adult health, highlighting the need to provide infants with food adequate in vitamin A to prevent the risks associated with vitamin A deficiency (VAD).

Soybean (*Glycine max*) is an annual leguminous crop and is grown to provide food for humans, feeds for animals and raw materials for industries [11]. It is an excellent source of protein (35-40%) which has made it popular in the West African sub-region [12]. Soybean seed is the richest in food value of all plant foods consumed in the world and it is rich minerals and vitamins that are well-known hematinic and are essential in the formation of red blood cells [13]. Soybean is processed into flour that is used as composite flour in the bakery industry [14,15] and in infant food manufacturing in the country due to its high nutritional value. In addition to its processing and consumption as a refreshing beverage (soymilk) in Nigeria, the flour from toasted seeds is added to prepared gruels/pap as food for infant and children.

Groundnut /peanut (*Arachis hypogaea*) is a legume which is widely grown as a food crop. It is a cheap source of vegetable protein and rich in vitamins, minerals and several bioactive compounds like procyanidins and catechins with several heart health nutrients like potassium, magnesium, copper, niacin, folates, phytoster and flavonoids, [16,17]. Partially defatted and non-defatted groundnut cake flour have been used to improve the nutritional quality of various cereal-based products [18,19].

A number of complementary foods have been developed. In Africa, especially in Nigeria, most of these complementary foods are cereal-based [9]. They are mostly formulated with maize as the major ingredient and complemented with soybean, cowpea and/or groundnut. The legumes are added to improve upon the fat and protein content of the food. The cereal-based complementary foods have been reported to be monotonous, bulky in addition to low energy and nutrient densities [20]. Hence there is the need for researches into other raw materials for the production of complementary foods with good functional properties to allow for ease of swallow by the infants and at the same time meet the energy and nutrient densities required for normal growth and performance. Functional properties are those intrinsic physico-chemical properties of food proteins that determine their behaviour in food system during processing, storage and consumption [21,22]. This study was therefore aimed at evaluating the physicochemical, functional and pasting properties of complementary food blend from orange-flesh sweet potato (OFSP) starch, soybean and groundnut flour and the evaluation its.

2. Materials and Methods

2.1. Materials

Orange flesh sweet potato (OFSP) Tuber (*Ipomea batata*) was purchased from the fruit garden market D'line, Port Harcourt, while soybean (*Glycine max*) and groundnut (*Arachis hypogea*) were purchased from Mile III market, Port Harcourt, Rivers State, Nigeria.

2.2. Production of Orange Flesh Sweet Potatoe Starch, Soybean and Groundnut Flour

The extraction of starch from OFSP and the production of soybean and groundnut flour are shown in Figure 1. The OFSP starch was extracted according to the method described by Nath et al., [23]. Briefly, the OFSP tubers were washed, pealed, grated, sieved to remove fibre, allowed to sediment for 12 h, dewatered, the wet mash was dried in a hot air oven (model QUB 305010G, Gallenkamp, UK) at 50°C for 1 h and then milled to obtain dry starch. Production of soybean and groundnut flour was according to the method by Dewey and Brown [24]. The soya tester was dehulled after washing and soaking in water for 6-18 h. The dehulled soybean was boiled for 20 min, oven dried at 50°C for 24 h, and roasted in a pan over an open gas flame for 10 min. Thereafter it was milled and sieved to obtain soybean flour. Washed groundnuts were sundried for 6 h, toasted in an oven at 70°C for 10 min, peeled and then milled to flour. The OFSP starch, soybean and groundnut flour were stored separated in airtight polyethylene bags till required for blending and analysis.

2.3. Formulation of OFSP Starch, Soybean and Groundnut Flour Complementary Food Blends

The composition of the OFSP starch, soybean and groundnut flour (OFSP: SB: GN) complementary food blend are shown in Table 1. OFSP starch served as the main carbohydrate source, with varying quantities of soybean (SB) flour and constant quantity of groundnut (GN) flour. The OFSP starch and flour of soybean and groundnut were homogenized in a rotatory mixer (Philips, HR1500/A, Holland), package in air tight plastic containers and stored in the refrigerator until required for analysis.

Table 1. Composition (%) of orange flesh sweet potato (OFSP) starch, soybean and groundnut flour complementary food blend (OFSP/SB/GN)

Samples	OFSP starch	Soybean flour (SB)	Groundnut flour (GN)
Control	100	0	0
PSG1	90	5	5
PSG2	85	10	5
PSG3	80	15	5
PSG4	75	20	5
PSG5	70	25	5
PSG6	65	30	5
PSG7	60	35	5
PSG8	55	40	5
PSG9	50	45	5

PSG = OFSP:SB:GN Complementary food blends.

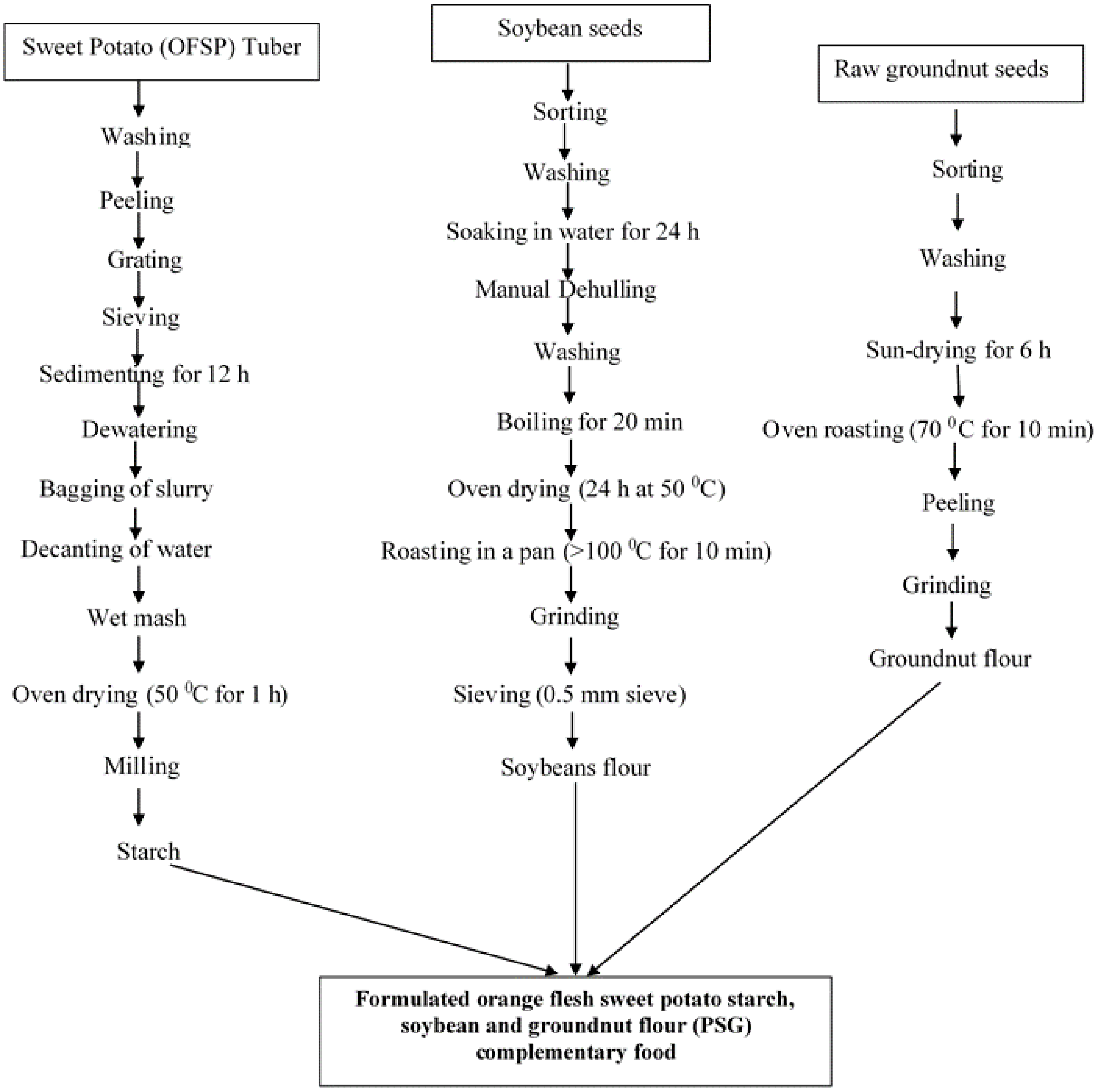

Figure 1. Production of orange flesh sweet potato starch (OFSP), soybean and groundnut flour and formulation of the complementary gruel

2.4. Determination of the Physicochemical Properties of OFSP Starch, Soybean and Groundnut Flour Complementary Food

Physicochemical properties of the complementary food analyzed were; pH, starch, sugars and carotenoid. pH was determined following the AOAC [25] standard method. Starch, sugar and amylose content were determined according to the method described by Eke *et al.*, [26], while amylopectin was determined by difference [27]. Total carotenoid was determined calorimetrically following the AOAC (974.29) [28] method. Briefly, to 100 mg of sample in a tube was added 10 ml of 80% acetone and centrifuged at 3000 rpm for 10 min. The supernatant was collected in another tube and the volume was make up to 10 ml with 80% acetone. The optical density of supernatant was measured at 480 nm in UV spectrophotometer. Total Carotenoid (mg/kg) was calculated as: (4 X Optical density x Volume of sample)/Weight of sample

2.5. Determination of the Functional Properties of OFSP Starch, Soybean and Groundnut Flour Complementary Food

2.5.1. Swelling Power And Solubility Index

The swelling power and solubility index was carried out using method of Takashi and Sieb [29]. One gram of The sample (1 g) was weighed and transferred into a 100 ml conical flask with the addition of 15ml of distilled water. The was thoroughly mixed and heated on a shaker bath (Gallenkamp, UK) at 100°C for 1 h. The content of the conical flask after cooling under running water was transferred into a weighed centrifuge tube and centrifuged at 3000 rpm for 30 min using a digital control centrifuge (L-600, China). The weight of the supernatant and the sediment was taken. The clear supernatant was transferred into a previously dried and weighed moisture can and was dried in the oven (DHG-9140A, China), cooled and weighed. Swelling power (g/g) was expressed as weight of sediment divided by the weight of the sample and the solubility index (%) was expressed as weight of dried matter from the supernatant divided by weight of the sample multiplied by 100.

2.5.2. Bulk Density

Bulk density was determined according to the standard method of AOAC, [25]. The OFSP starch, soybean and groundnut flour complementary food (5 g) was added to a 50 ml graduated measuring cylinder. The cylinder was tapped gently until the samples was closely packed. The volume occupied by the sample was noted and the bulk density (g/cm3) was calculated as weight of garri (g) divided by volume (cm3) of the garri.

2.5.3. Water Absorption Capacity

The water absorption capacity of the samples was determined as described by Beuchat [30]. The sample (1 g) in 10 ml of distilled water in a centrifuge tube was thoroughly mixed for 20 min on a multifunctional shaker. The sample was allowed to stand at room temperature (28+10C) for 30 min and then centrifuged at 3500 rpm for 30 min. The volume of the supernatant was measured and the water absorbed (ml/g) was calculated as the amount of water absorbed divided by the initial volume of water.

2.5.4. Dispersibility

This was determined by the method described by Akanbi *et al*., [31]. Briefly, to 10 g of the sample in a measuring cylinder was added100 ml of distilled water left to stand for 3 h during which pure and sediment layers were formed. The volume of the sediment was noted and dispersibility (%) calculated as the difference between the initial volume of water and the sediment.

2.5.5. Least Gelation Concentration (LGC)

Least gelation concentration was determined by the method of Sathe and Salunkhe [32]. Sample suspensions (2 % w/v) was prepared in a test tube and heated in a boiling water bath for 1 h followed by rapid cooling under running cold tap water. The test tube was further cooled for 2 h at 4°C. Least gelation concentration was determined as that concentration when the sample from the inverted test tube did not fall down or slip.

2.6. Pasting Properties

The pasting characteristic of the diets was determined by AOAC [25] using a Rapid visco analyzer. The moisture content of the complementary diet was determined to obtain the correct sample weight and amount of water required for the test. An aqueous suspension of sample was made and spun in the analyzer following the standard instructions. Viscosities (Peak, trough, final viscosity, breakdown and setback) was expressed in rapid viscosity units (RVU) while temperature and time was expressed in degree Celsius (°C) and minutes (min) respectively

2.7. Statistical Analysis

Analysis were carried out in duplicates. Data were subjected to Analysis of Variance (ANOVA) and the means were separated using Tukey's pairwise comparison test at a probability level of 0.05 (P<0.05) using Minitab (Release 16.0) Statistical Software English (Minitab Ltd. Coventry, UK).

3. Results and Discussion

3.1. Physicochemical Properties of OFSP Starch, Soybean and Groundnut Flour Complementary Food

Figure 2 showed the pH of the OFSP starch, soybean and groundnut flour complementary food, while the starch, sugar, amylose, amylopectin and carotene content are presented in Table 2. There was a significant (P<0.05) increase in pH of the complementary food with increase in substitution of soybean flour. The values varied from 4.60 – 5.69 for the Control and sample I (with 50% soybean flour substitution.

Table 2. Starch, sugar, amylose, amylopectin (%) and carotenoid (mg/100g) contents of the orange flesh sweet potato starch, soybean and groundnut flour complementary food blend

Samples	Starch	Sugar	Amylose	Amylopectin	Carotenoid
Control	71.22^{ef}±0.85	0.73^{f}±0.22	29.71^{a}±0.04	70.29^{f}±0.40	32.16^{b}±1.64
PSG1	87.53^{a}±0.64	$1.07d^{ef}$±0.17	24.94^{b}±0.04	75.06^{e}±0.04	22.77^{d}±0.26
PSG2	79.16^{bc}±0.32	0.82^{ef}±0.30	25.98^{b}±0.13	74.02^{e}±0.13	28.54^{c}±0.11
PSG3	70.83^{ef}±1.66	1.12^{def}±0.04	18.54^{c}±0.04	81.47^{d}±0.04	29.30^{bc}±0.71
PSG4	80.87^{b}±0.19	2.21^{b}±0.09	19.31^{c}±0.04	80.69^{d}±0.04	44.60^{a}±0.40
PSG5	$73.94d^{e}$±1.08	1.45^{cde}±0.03	18.88^{c}±0.05	81.12^{d}±0.26	20.90^{d}±1.22
PSG6	76.07^{cd}±1.15	1.82^{bc}±0.23	17.93^{cd}±0.17	82.07^{cd}±0.17	11.08^{e}±0.26
PSG7	80.78^{bc}±1.21	3.64^{a}±0.21	16.43^{d}±0.13	83.57^{bc}±0.13	30.69^{bc}±0.62
PSG8	69.51^{cf}±2.31	1.63^{bcd}±0.03	14.54^{e}±1.34	85.47^{a}±1.34	20.72^{d}±0.84
PSG9	69.09^{f}±0.97	0.71^{f}±0.09	14.66^{e}±0.30	85.34^{ab}±0.30	21.19^{d}±0.17

Values are mean ± standard deviation of duplicate samples
Means bearing different superscripts in the same column differ significantly (P<0.05)
Control = 100 (OFSP): 0 (Soybean flour): 0 (Groundnut flour); PSG1 = 90 (OFSP): 5 (Soybean flour): 5 (Groundnut flour)
PSG2 = 85 (OFSP): 10 (Soybean flour): 5 (Groundnut flour); PSG3 = 80 (OFSP): 15 (Soybean flour): 5 (Groundnut flour)
PSG4 = 75 (OFSP): 20 (Soybean flour): 5 (Groundnut flour); PSG5 = 70 (OFSP): 25 (Soybean flour): 5 (Groundnut flour)
PSG6 = 65 (OFSP): 30 (Soybean flour): 5 (Groundnut flour); PSG7 = 60 (OFSP): 35 (Soybean flour): 5 (Groundnut flour)
PSG8 = 55 (OFSP): 40 (Soybean flour): 5 (Groundnut flour); PSG9 = 50 (OFSP): 45 (Soybean flour): 5 (Groundnut flour)

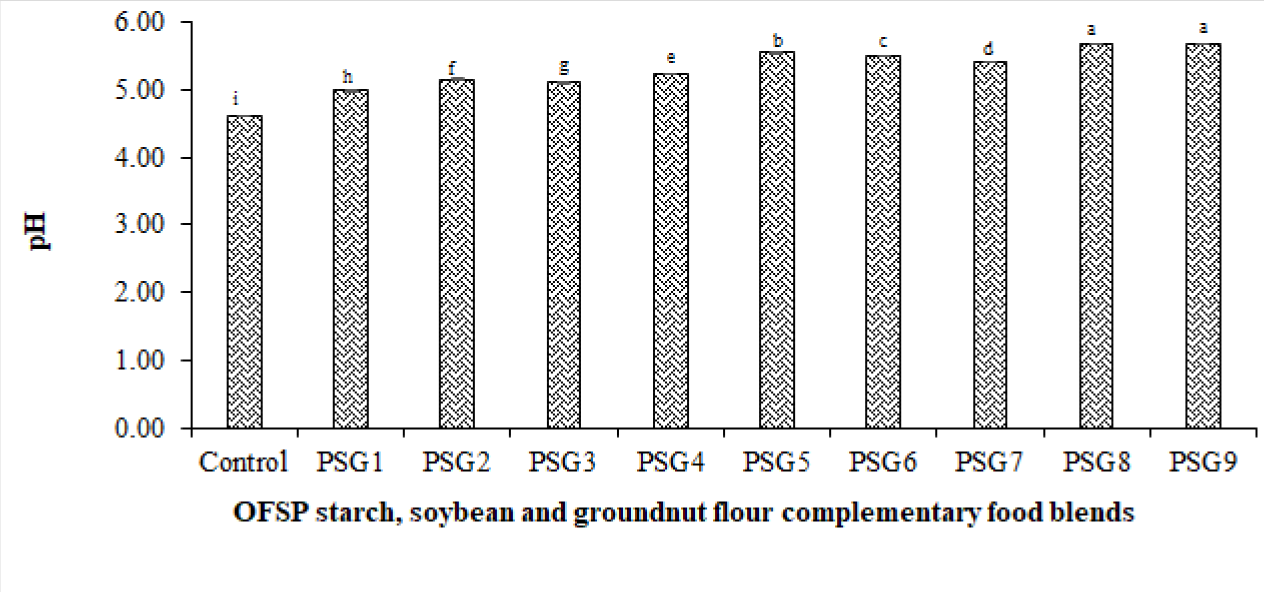

Figure 2. pH of orange flesh sweet potato (OFSP) starch, soybean and groundnut flour complementary food [Bars and error bars represent the mean and standard deviation of duplicate samples. Bars bearing different superscripts differ significantly (P<0.05). Control = 100 (OFSP): 0 (Soybean flour): 0 (Groundnut flour); PSG1 = 90 (OFSP): 5 (Soybean flour): 5 (Groundnut flour); PSG2 = 85 (OFSP): 10 (Soybean flour): 5 (Groundnut flour); PSG3 = 80 (OFSP): 15 (Soybean flour): 5 (Groundnut flour); PSG4 = 75 (OFSP): 20 (Soybean flour): 5 (Groundnut flour); PSG5 = 70 (OFSP): 25 (Soybean flour): 5 (Groundnut flour); PSG6 = 65 (OFSP): 30 (Soybean flour): 5 (Groundnut flour); PSG7 = 60 (OFSP): 35 (Soybean flour): 5 (Groundnut flour); PSG8 = 55 (OFSP): 40 (Soybean flour): 5 (Groundnut flour); PSG9 = 50 (OFSP): 45 (Soybean flour): 5 (Groundnut flour)]

The starch content ranged from 69.08 - 87.53 %. PSG1 (with 5 % soybean flour) had significantly (P<0.05) the highest starch content while PSG9 (with 50 % soybean flour) had the least. Though there were significant variations in the starch content of the complementary food the general trend was a decrease with the increase in soybean substitution. The starch content of a food material affects certain properties like swelling, gelatinization, pasting and suitability for processing that food material [33].

The Sugar content of the complementary food increased with increase in soybean substitution with significant variations. Values obtained varied between 0.73 and 3.64 %. The control had significantly (P>0.05) the least value and PSG 7 with 35 % soybean substitution had the highest sugar content. The result was in line with that reported by Mitra, [34]. Sugar contributes to the sweetness of any product.

Amylose content ranged from 14.53 - 29.713 %. The control had significantly (P<0.05) the highest amylose content while PSG8 with 45 % soybean substitution had the least. Amylose content of the formulated complementary foods decreased with increase substitution of soybean. Amylose is the linear components of starch. It imparts definite characteristics to starch and therefore, its content is an important criterion in starch quality [27]. Amylopectin content has an inverse correlation with the Amylose content, thus, it increased with increased substitution of soybean in the food. The values ranged from 70.28 - 85.46 % respectively, for the control and sample I with 50% soybean substitution.

Carotenoid content of the formulated gruel ranged from 11.08 - 44.60 mg/kg, with significantly (P<0.05) highest value recorded for PSG4. The carotenoid content agreed with the β-carotene range of 29.12 – 47.43 mg/kg reported by Oguizu. [35] for OFSP/soya bean complementary food. The recommended safe intake of Vitamin A for infants between 0 - 6 months is 375 µg/RE/day [36]. The retinol equivalent for carotenoids is 12 µg hence, the carotenoid content of the orange flesh sweet potato starch, soybean and groundnut flour will meet 246 - 991% of the Vitamin A requirement. The blends are therefore, an excellent source of β-carotene which is the precursor of vitamin A. The OFSP is considered as the good source of the carotenoids, and has recommended its use to combat the problems of Vitamin deficiency (VAD) in developing countries [37].

3.2. Functional Properties of OFSP Starch, Soybean and Groundnut Flour Complementary Food

Functional properties evaluate the roles and functions of specific component in foods or how ingredients behave during preparation and cooking, Wijaya and Mehta [38] thus determined their end use. Functional properties: bulk density, water absorption capacity, swelling power, solubility and dispersibility of the OFSP starch, soybean and groundnut complementary food are shown in Table 3. Bulk density ranged from 0.71 - 0.83 g/ml. The result was comparable those of millet, soybean and sweet potato complementary food [39]. The control had significantly (P<0.05) the least bulk density while there was no significant (P>0.05) in the bulk densities of the formulated complementary food. Plaami, [40] reported that bulk density is influenced by the structure of the starch polymers and loose structure of the starch polymers could result in low bulk density. This implies that the control sample had more loosed starch structure than the soybean and groundnut substituted samples.

Table 3. Functional properties of the orange flesh sweet potato starch, soybean and groundnut flour complementary food blend

Sample	Bulk density (g/ml)	Water absorption capacity (%)	Swelling power (%)	Solubility (%)	Dispersibility (%)	Least gelation concentration (%)
Control	$0.71^{b}\pm0.00$	$0.59^{e}\pm0.01$	$14.48^{a}\pm0.02$	$9.45^{a}\pm1.22$	$78.00^{ab}\pm1.41$	2
PSG1	$0.79^{a}\pm0.02$	$0.59^{e}\pm0.01$	$13.99^{ab}\pm0.26$	$8.14^{ab}\pm1.160$	$78.00^{ab}\pm0.00$	2
PSG2	$0.80^{a}\pm0.01$	$0.78^{d}\pm0.01$	$12.94^{bc}\pm0.55$	$5.72^{b}\pm0.66$	$80.00^{a}\pm0.00$	2
PSG3	$0.80^{a}\pm0.02$	$0.79^{d}\pm0.01$	$11.99^{cd}\pm0.19$	$5.57^{b}\pm0.00$	$78.00^{ab}\pm1.41$	2
PSG4	$0.82^{a}\pm0.00$	$1.00^{c}\pm0.01$	$10.03^{ef}\pm0.71$	$6.09^{b}\pm0.44$	$78.00^{ab}\pm1.41$	2
PSG5	$0.83^{a}\pm0.01$	$0.99^{c}\pm0.01$	$10.57^{dc}\pm0.38$	$6.39^{b}\pm0.26$	$78.00^{ab}\pm1.41$	2
PSG6	$0.82^{a}\pm0.00$	$1.07^{bc}\pm0.11$	$10.01^{ef}\pm0.43$	$6.26^{b}\pm0.98$	$76.00^{b}\pm0.00$	2
PSG7	$0.79^{a}\pm0.03$	$1.34^{a}\pm0.00$	$9.75^{ef}\pm0.05$	$6.28^{b}\pm0.97$	$78.00^{ab}\pm0.00$	2
PSG8	$0.82^{a}\pm0.02$	$1.16^{b}\pm0.03$	$9.54^{ef}\pm0.20$	$5.95^{b}\pm0.29$	$76.00^{b}\pm0.00$	2
PSG9	$0.82^{a}\pm0.01$	$1.35^{a}\pm0.02$	$9.12^{f}\pm0.14$	$6.96^{ab}\pm0.912$	$80.00^{a}\pm1.41$	2

Values are mean ± standard deviation of duplicate samples
Means bearing different superscripts in the same column differ significantly (P<0.05)
Control = 100 (OFSP): 0 (Soybean flour): 0 (Groundnut flour); PSG1 = 90 (OFSP): 5 (Soybean flour): 5 (Groundnut flour)
PSG2 = 85 (OFSP): 10 (Soybean flour): 5 (Groundnut flour); PSG3 = 80 (OFSP): 15 (Soybean flour): 5 (Groundnut flour)
PSG4 = 75 (OFSP): 20 (Soybean flour): 5 (Groundnut flour); PSG5 = 70 (OFSP): 25 (Soybean flour): 5 (Groundnut flour)
PSG6 = 65 (OFSP): 30 (Soybean flour): 5 (Groundnut flour); PSG7 = 60 (OFSP): 35 (Soybean flour): 5 (Groundnut flour)
PSG8 = 55 (OFSP): 40 (Soybean flour): 5 (Groundnut flour); PSG9 = 50 (OFSP): 45 (Soybean flour): 5 (Groundnut flour)

Water absorption capacity (WAC) varied significantly (P<0.05) from 0.59 - 1.35 % for the control and PSG9 respectively. This result was in line with the report by Addis *et al.*, [41] for sorghum, pigeon pea, soybean, skimmed milk and sucrose complementary food. WAC is the ability of the starch or flour to absorb water, swell for improved consistency and texture [42]. The capability of food materials to absorb water to a large extent is associated to its protein content [21]. There was significant (P<0.05) increase with increase in soybean substitution. This could be attributed to the protein content of the soybean flour.

The Swelling power of the OFSP starch, soybean and groundnut formulated complementary food decreased significantly (P<0.05) with increase in treatment levels, from 9.12 - 14.48 in the control and PSG9 respectively. This was higher than the report by Olatunde *et al.*, [39]. Swelling power of flour granules depends on the particle size, types and variety of raw materials and the preparation methods [43]. It is an indication of the extent of associative forces inside the granule and degree of exposure of the internal structure of the starch present in the flour to the action of water [44,45]. The addition of soybean must have resulted in more exposure of the starch internal, thus, leading to increase in swelling power of the complementary food. The increase in swelling power is desirable for a nutrient dense gruel required for infant feeding.

The solubility index ranged from 5.57 - 9.45. The solubility test showed that the control sample was significantly (P<0.05) more soluble than the soybean groundnut substituted samples. High solubility of food can show high digestibility of the food which may indicate excellent use for infant formula and food [46].

Dispersibility ranged from 76.00 - 80.00 %. PSG2 and PSG9 had significantly (P<0.05) the highest dispersibility while PSG6 and PSG8 had the least. Dispersibility indicates reconstitution ability and it is the ability of flour to be wet without the formation of lumps, with simultaneous disintegration of agglomerates [47,48]. The dispersibilities of the formulated complementary food therefore indicates that they will not form lumb during gruel preparation which is acceptable for infant feeding, though the method of gruel preparation may also play a role.

The least gelation concentration is the lowest protein concentration at which gel remained in the inverted tube [49]. It measures the minimum amount of flour needed to form a gel in a measured volume of water and the lower LGC the better the gelatin and swelling power of the flour [50]. The LGC for all the samples was 2 %, this implies that any little amount of the formulated complementary food will form a gel. This is needed for the preparation of nutrient dense gruel.

3.3. Pasting Properties of OFSP Starch, Soybean and Groundnut Flour Complementary Food

Pasting is the result of a combination of processes that follows gelatinization from granule rupture to subsequent polymer alignment due to mechanical shear during the heating and cooling of starches Omueti *et al.*, [51]. The pasting properties of the OFSP starch, soybean and groundnut flour complementary food are shown in Table 4. The peak, trough, breakdown, final viscosities and setback varied significantly (P<0.05) from 127.5 - 7291.0, 95.3 - 4332.0, 32.3 - 2959.0, 129.0 -6159.0 and 33.79 - 1827.0 RVU respectively. There was significantly (P<0.05) decrease in the viscosities of the complementary food with increase in soybean flour addition. The control had significantly (P<0.05) the highest viscosities and PSG9 had the least. Peak viscosity is the maximum viscosity developed during or soon after heating [27]. It is an indicative of the strength of the pastes which are formed from gelatinization during processing in food application and higher peak viscosity corresponds to a higher thickening power of the starch [52]. Breakdown viscosities reflects the stability of the peak viscosity during processing [53]. Final viscosities are important in determining processing, while setback viscosity indicates gel stability and potential for retrogradtion [54]. This determines the ability to form gel during processing [55]. The reduction in the viscosities of the soybean and groundnut substituted complementary food is an indication of reduction in their thickening power, hence they will form low viscous gruel rather than a very thick gruel. This is very important in achieving high nutrient dense gruel yet thin enough for infant feeding. Also, the low setback suggests that the OFSP starch, soybean and groundnut flour complementary food during preparation for feeding will not be cohesive. This is in agreement with the report by Omueti *et al.,* [51].

The peak time and temperature ranged respectively from 4.33 - 4.70 min and 82.48 - 85.68°C. The pasting temperature is the temperature at which the viscosity starts to rise [27,56] while the peak time is time in minutes at which the peak viscosity occurred. Pasting temperature increased significantly (P<0.05) with increase substitution of soybean flour while the reverse was the case with the peak time. This implies that the substituted samples required more less time and higher temperatures to form a paste than the control. The attainment of the pasting temperature is essential in ensuring swelling, gelatinization and subsequent gel formation during processing [51].

Table 4. Pasting properties of the orange flesh sweet potato starch, soybean and groundnut flour complementary food blend

Sample	Peak viscosity (RVU)	Trough viscosity (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Set back (RVU)	Peak time (min)	Pasting temperature (^{o}C)
Control	$7291.0^{a}\pm125.90$	$4332.0^{a}\pm158.40$	$2959.0^{a}\pm32.50$	$6159.0^{a}\pm131.50$	$1827.0^{a}\pm26.87$	$4.70^{a}\pm0.04$	$82.48^{h}\pm1.16$
PSG1	$503.70^{b}\pm21.20$	$250.3^{b}\pm8.80$	$253.4^{b}\pm12.40$	$373.6^{b}\pm4.50$	$123.33^{b}\pm4.24$	$4.33^{d}\pm0.000$	$83.25^{b}\pm0.03$
PSG2	$449.2^{bc}\pm6.60$	$236.0^{b}\pm6.00$	$213.2^{bc}\pm0.60$	$356.7^{bc}\pm4.00$	$120.66^{b}\pm2.00$	$4.44^{cd}\pm0.050$	$83.70^{b}\pm0.495$
PSG3	$397.2^{bcd}\pm6.80$	$222.0^{b}\pm1.20$	$175.2^{cd}\pm8.10$	$346.7^{bc}\pm9.40$	$115.75^{bc}\pm2.12$	$4.50^{bc}\pm0.04$	$84.15^{ab}\pm0.07$
PSG4	$337.7^{cde}\pm12.40$	$189.0^{b}\pm5.10$	$148.7^{d}\pm7.40$	$300.6^{bc}\pm8.00$	$111.63^{bc}\pm2.89$	$4.40^{cd}\pm0.000$	$83.30^{b}\pm0.071$
PSG5	$304.6^{cde}\pm0.40$	$175.1^{b}\pm4.10$	$129.5^{de}\pm4.50$	$224.1^{bcd}\pm3.00$	$99.00^{bcd}\pm1.06$	$4.44^{cd}\pm0.050$	$83.73^{b}\pm0.601$
PSG6	$250.9^{def}\pm21.60$	$155.8^{b}\pm9.90$	$95.1^{ef}\pm11.70$	$235.9^{bcd}\pm18.90$	$80.09^{cd}\pm8.96$	$4.50^{bc}\pm0.042$	$83.13^{ab}\pm0.035$
PSG7	$195.4^{ef}\pm11.30$	$126.8^{b}\pm6.50$	$68.6^{fg}\pm4.60$	$189.2^{cd}\pm10.80$	$62.34^{de}\pm4.36$	$4.50^{bc}\pm0.04$	$83.70^{b}\pm0.63$
PSG8	$205.9^{ef}\pm3.40$	$135.3^{b}\pm2.10$	$70.6^{fg}\pm1.20$	$197.7^{cd}\pm2.70$	$62.45^{de}\pm0.53$	$4.47^{cd}\pm0.00$	$84.05^{ab}\pm0.07$

Values are mean ± standard deviation of duplicate samples
Means bearing different superscripts in the same column differ significantly (P<0.05)
Control = 100 (OFSP): 0 (Soybean flour): 0 (Groundnut flour); PSG1 = 90 (OFSP): 5 (Soybean flour): 5 (Groundnut flour)
PSG2 = 85 (OFSP): 10 (Soybean flour): 5 (Groundnut flour); PSG3 = 80 (OFSP): 15 (Soybean flour): 5 (Groundnut flour)
PSG4 = 75 (OFSP): 20 (Soybean flour): 5 (Groundnut flour); PSG5 = 70 (OFSP): 25 (Soybean flour): 5 (Groundnut flour)
PSG6 = 65 (OFSP): 30 (Soybean flour): 5 (Groundnut flour); PSG7 = 60 (OFSP): 35 (Soybean flour): 5 (Groundnut flour)
PSG8 = 55 (OFSP): 40 (Soybean flour): 5 (Groundnut flour); PSG9 = 50 (OFSP): 45 (Soybean flour): 5 (Groundnut flour)

4. Conclusion

The formulated OFSP starch, soybean and groundnut flour complementary food had a significant (P<0.05)) increase, in pH, sugar, amylopectin, carotenoid bulk density, water absorption capacity and dispersibility with increase in soybean addition. The carotenoid content will meet >200% of the recommended Vitamin A requirement for infants. However, swelling power, solubility and viscosities from the pasting properties decreased significantly with increase in soybean substitution. This reduction is very important in achieving high nutrient dense gruel yet thin enough for infant feeding.

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