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Physico-Chemical, Pasting and Sensory Properties of Food Blends of Maize, Yellow Cassava or Sweet Potato Starch, Defatted Soybean and Groundnut Flour

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Abstract Gruel was produced from different formulations of maize, yellow cassava or sweet potato starches; defatted soybean and groundnut flours. Eighteen blends were produced with 100% maize as the control. The recipe formulations for the products were 100:0:0, 90:5:5, 85:10:5, 75:20:5, and 70:25:5 of the various starches, soybean and groundnut flours respectively. The eighteen formulated products were subjected to chemical, functional, pasting and sensory analysis. There were significant differences ($p \leq 0.05$) in all the parameters investigated. The protein content ranged from 0.50 to 20.45%, fat content from 0.29 to 8.93% while the ash content ranged from 0.09 to 1.24%. The moisture values ranged from 9.5 to 14.15%, while carbohydrate content ranged from 60.14 to 84.22%. Amylose and amylopectin ranged from 21.06 to 29.25% and from 70.75 to 78.94% respectively. Starch and sugar contents ranged from 2.48 to 4.95% and from 56.57 to 70.15% respectively. The functional properties also varied due to differences in starch sources. Dispersibility ranged from 69.00 to 81.25% while bulk density ranged from 0.31 to 0.53g/ml. Swelling power and solubility ranged from 6.02 to 8.30% and from 1.30 to 14.39% respectively. Water absorption capacity ranged from 0.77 to 2.16% and least gelation concentration from 4 to 8%. Pasting properties of the starches showed that peak and break down viscosities ranged from 158.18 to 620.54RVU and 63.43 to 419.38RVU. Trough and final viscosities ranged from 92.90 to 241.48RVU and 157.00 to 310.72RVU, while setback viscosity value ranged from 50.12 to 113.25RVU. Pasting time ranged from 3.55 to 4.61min, while pasting temperature ranged from 70.94 to 81.21°C. All pasting parameters decreased with an increase in the level of protein substitution except pasting time and temperature that increased with the level of substitution. The sensory panelists rated the products highly for all the parameters investigated. Products MSG_5 (70%M; 25%S; 5%G), PSG_5 (70%P; 25%S; 5%G) and CSG_5 (70%C; 25%S; 5%G) showed no significant difference ($p \geq 0.05$) in their acceptability to consumers and were thus the most preferred samples. The study showed that an acceptable gruel can be produced from yellow cassava or sweet potato starches with the addition of defatted soybean and groundnut flour at 25% and 5% substitution levels respectively.

Keywords: *food blends, starches, soybean, groundnut flour, physico-chemical, pasting, sensory*

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1. Introduction

In Nigeria, the traditional weaning food is a cereal gruel made from maize or guinea corn which can be prepared individually or as a composite gruel [1]. It is called different names by different cultures: "pap", "akamu" or "ogi" [2]. This gruel however, is known to be of low nutritive value and is characterized by low protein-energy density and high bulk. Maize has been implicated in the etiology of protein-energy malnutrition in children during weaning. The protein content is of low quality; low in lysine and tryptophan, two amino acids that are indispensable to the growth of children. Several studies have shown that although maize gruel provided energy, it lacked other necessary nutrients needed for growth. The study carried out by Agu [3] observed that pap (gruel) contained only 0.5% protein and less than 1% fat as compared with the 9% protein and 4% fat in the raw maize. This means that processing has a negative effect on the product. Akinrele and Edwards [4] concluded that the protein content of the maize gruel was too low to even support the growth of rats.

Gruel is also consumed as a breakfast meal by many and could be regarded as a food of choice for the sick [5], supplemented with the animal protein milk, if and where available due to its cost. Consistent consumption of this food without adequate protein intake might eventually lead to malnutrition hence the addition of soybean and groundnut which are available and inexpensive sources of protein from plants. Maize has been the staple raw material for the production of gruel for family use over the years. Due to the increase in the demand of maize for household use as well as feed for livestock, there has been a drastic increase in the demand and price of maize which has necessitated the need for alternative starches that can also serve the same purpose for children as weaning foods as well as for family use.

Adequate processing and judicious blending of the locally available foods could result in improved intake of nutrients to prevent malnutrition related problems like kwashiorkor and/or marasmus [6].

Cassava *(Manihot esculenta)* and sweet potatoes *(Ipomea batatas L.)* are staple crops in tropical countries cultivated for their starchy tuberous roots. The use of these starchy roots in the formulation of food blends will require additional fortification with foods like legumes such as groundnut and soybean. Groundnut and soybean provides an inexpensive source of high quality protein and oil. Soybean is one of the richest and cheapest sources of protein from plant origin, high in fiber, isoflavones, essential fatty acids and low in carbohydrates. Therefore, the objectives of the study are:

To formulate food gruel from blends of maize, yellow cassava or sweet potato starches, with soybean and groundnut flour.

To determine the sensory, chemical, functional and pasting properties of the blends.

2. Materials and Methods

2.1. Raw Materials

Yellow cassava *(Manihot esculenta)* used for this study was purchased from a demonstration farm in Ogba Egbema Ndoni Local Government Area, sweet potato *(Ipomea batatas L.),* maize *(Zea mays),* soybean *(Glycine max)* and groundnut *(Arachis hypogaea)* were purchased from mile 3 market in Diobu, Port Harcourt, both in Rivers State. Nigeria.

2.1.1. Preparation of Yellow Cassava, Sweet Potato and Maize Starch [7]

Cassava and sweet potato roots were peeled manually with the aid of stainless steel kitchen knives while maize grains were sorted. They were all washed separately, milled, sieved, allowed to sediment, decanted and dried in an air circulating oven at 50°C for 24hours. The dried starch was then milled to fine powder.

2.1.2. Preparation of Defatted Soybean Flour [8]

Soybean seeds were sorted, washed and roasted until light brown. The seeds were then boiled for 20minutes, decorticated, drained, dried at 100°C for 3-4hours before being dry milled. The milled soybean was then defatted using hexane.

2.1.3. Preparation of Defatted Groundnut Flour [9]

Groundnut seeds were sorted, washed and roasted until light brown. The seeds were then decorticated and milled. It was then defatted using hexane.

2.1.4. Preparation of Starch Blends

The blends were prepared with graded levels (70% to 100%) of maize, cassava or sweet potato starches separately with added quantities of defatted soybean and groundnut flour. The levels ranged from 5% to 25% soybean and 5% groundnut which were constant in all the blends.

2.2. Functional Properties of Food Blends

Relative bulk density of food blends were determined by the method of Narayana and Narasinga [9], while swelling power and solubility was determined according to the method of Takashi and Sieb [10]. Dispersibility was determined by the method of Kulkarni *et al.,* [11]. Water absorption capacity and least gelation concentration were determined by the methods of Onwulata *et al.,* [12] and Sathe *et al.,* [13].

2.3. Chemical Analysis of Food Blends

The moisture content of the samples were determined using moisture analyzer AMB-ML-50 at 130°C. Ash, fat and crude protein contents were determined according to the method described by AOAC [14]. The amylose content of starch extracted from the samples were determined using the iodine calometric method reported by Zakpaa *et al.,* [15], while amylopectin was calculated by difference

2.4. Pasting Properties of the Food Blends

Pasting properties of the flour blends were characterized using the Rapid Visco Analyzer (RVA Model 3c, Newport Scientific PTY ltd, Sydney) as described by Sanni [16].

2.5. Sensory Evaluation

The gruels were prepared with the ratio 1:8 weight/volume of starch to water for sensory analysis. The evaluation was done using twenty semi-trained staff and students of the Department of Food Science and Technology, Rivers State University, who were not sick or allergic to any component raw material used in the preparation of the blends. Eighteen coded samples of gruels were presented to each panelist. The assessment was based on color, aroma, taste, texture, consistency, mouth feel and general acceptability using a nine point hedonic scale [17] ranging from like extremely to dislike extremely. Samples were served in disposable plates and water was presented for mouth rinsing between samples.

2.6. Statistical Analysis

The data obtained were subjected to analysis of variance (ANOVA). All analysis was done in duplicates using the Duncan Multiple Range Test (DMR) to separate the mean.

3. Results

3.1. Sensory Evaluation of Food Blends (Gruels)

Table 1: Shows the sensory evaluation results of gruels produced from maize, yellow cassava or sweet potato starches; defatted soybean and groundnut flours. Color of

the gruel ranged from 5.75 to 7.90 with sample MSG_5 (70%M; 25%S; 5%G) as the most preferred and sample C (100% Yellow cassava) as the least preferred. There were significant differences ($p \leq 0.05$) in color

Gruel aroma ranged from 5.10 to 7.15 with samples MSG_1 (90%M; 5%S; 5%G), C (100% Yellow cassava) and CSG_3 (80%C; 15%S; 5%G) as the least preferred and PSG_4 (75%P; 25%S; 5%) as the most preferred.

Sample CSG_5 (70%C; 25%S; 5%G) was the most preferred in consistency at 7.55, while sample MSG_2 (85%M; 10%S; 5%G) was the least preferred with 5.35.

Mouth feel ranged from 5.25 to 7.10 with sample MSG_2 (85%M; 10%S; 5%G) as the least preferred and sample MSG_5 (75%M; 25%S; 5%G) as the most preferred. General acceptability ranged from 5.55 to 7.40 with sample C (100% Yellow cassava) as the least acceptable and sample MSG_5 (75%M; 25%S; 5%G) as the most acceptable.

The addition of defatted soybean and groundnut flour contributed significantly to the acceptability of the gruel. Sample PSG_4 (75%P; 20%S; 5%G) had a significantly different ($p \leq 0.05$) taste than the control at 7.15 and 5.90 respectively. Sample CSG_5 (70%C; 25%S; 5%G) and PSG_5 (70%C; 25%S; 5%G) also showed a significant difference ($p \leq 0.05$) at 7.10, 7.00 and 6.45 respectively.

3.2. Chemical Composition of Food Blends (Gruel)

Table 2: Shows the results of the chemical composition of gruels produced from maize, yellow cassava or sweet potato starches; defatted soybean and groundnut flours. Moisture content ranged from 9.5% to 14.15% with sample MSG_5 (75%M; 25%S; 5%) as the lowest and sample CSG_1 (90%C; 5%S; 5%G) as the highest. Moisture content ranging from 9.50% to 14.15% is slightly higher than the findings of Eke-Ejiofor and Owuno [18] with a value of 7.36% to 11.42%. Sanni *et al.,* [16] reported that the lower the moisture content of a product to be stored, the better the shelf stability of such product. The results of this study showed that the maize gruel had lower moisture content than the blends of yellow cassava and sweet potato. It also showed that moisture content decreased with an increase in the level of substitution of the protein sources.

Fat content ranged from 0.29% to 8.93% with sample P (100% Sweet potato) as the lowest and sample MSG_5 (75%M; 25%S; 5%G) as the highest. Fat result showed significant differences ($p \leq 0.05$) and increased with an increase in the level of substitution of the protein sources. The increase in fat and protein is in agreement with the findings of Ayinde and Olusegun [19].

Protein content ranged from 0.5% to 20.45% with sample C (100% Yellow cassava) as the lowest and MSG_5 (75%M; 25%S; 5%G) as the highest. Protein content increased with an increase in the level of substitution of the protein sources, showing a significant difference ($p \leq 0.05$).

Ash content ranged from 0.09% to 1.24% with sample M (100% Maize) as the lowest and sample CSG_4 (75%C; 20%; 5%G) as the highest. Ash content also showed an increase in content with an increase in the protein sources from 0.09% to 1.24% with the control, sample M (100% M) as the lowest and sample CSG_4 (75%C; 20%S; 5%G) as the highest. The amount of inorganic constituent present as measured by the ash content conveys an impression of the quality of metal ions bound to the raw material [20].

Table 1. Sensory Evaluation of Gruel Produced from Yellow Cassava, Sweet Potato or Maize Starch with Defatted Soybean and Groundnut Flour

Sample	Color	Aroma	Taste	Texture	Consistency	Mouth Feel	General Acceptability
M(control)	$6.90^{b} \pm 0.50$	$6.20^{c} \pm 1.00$	$5.90^{c} \pm 2.00$	$6.05^{c} \pm 0.50$	$5.95^{c} \pm 0.50$	$6.15_{b} \pm 0.50$	$6.45^{b} \pm 0.50$
MSG_1	$6.70^{b} \pm 1.00$	$6.05^{c} \pm 2.00$	$5.60^{c} \pm 1.50$	$5.85^{c} \pm 0.20$	$5.80^{c} \pm 1.00$	$5.35_{c} \pm 0.50$	$6.20^{c} \pm 0.50$
MSG_2	$6.15^{b} \pm 0.50$	$6.10^{c} \pm 0.00$	$5.90^{c} \pm 0.50$	$5.45^{c} \pm 1.50$	$5.35^{c} \pm 1.00$	$5.25_{c} \pm 0.50$	$6.05^{c} \pm 1.00$
MSG_3	$6.53^{b} \pm 0.00$	$6.45^{b} \pm 0.50$	$5.95^{c} \pm 2.00$	$5.85^{c} \pm 2.00$	$5.90^{c} \pm 1.00$	$5.55^{c} \pm 1.50$	$5.90^{c} \pm 1.00$
MSG_4	$6.60^{b} \pm 2.00$	$6.45^{b} \pm 0.50$	$6.35^{b} \pm 0.50$	$6.30^{b} \pm 1.50$	$6.40^{b} \pm 1.50$	$6.20^{b} \pm 0.00$	$6.55^{b} \pm 0.00$
MSG_5	$7.90^{a} \pm 1.50$	$6.20^{c} \pm 0.50$	$6.75^{b} \pm 0.50$	$6.95^{a} \pm 1.00$	$7.10^{a} \pm 0.60$	$7.10^{a} \pm 0.00$	$7.40^{a} \pm 1.00$
P	$6.45^{b} \pm 0.00$	$7.00^{a} \pm 0.50$	$6.25^{c} \pm 2.50$	$5.30^{b} \pm 3.50$	$6.30^{b} \pm 1.00$	$6.20^{b} \pm 2.50$	$6.70^{a} \pm 0.50$
PSG_1	$6.90^{a} \pm 0.50$	$5.70^{c} \pm 0.20$	$5.70^{c} \pm 0.00$	$5.65^{c} \pm 0.30$	$6.20^{b} \pm 0.50$	$5.80^{b} \pm 1.50$	$6.35^{b} \pm 0.50$
PSG_2	$6.10^{a} \pm 1.00$	$5.95^{c} \pm 0.50$	$6.15^{c} \pm 1.00$	$6.00^{c} \pm 0.30$	$6.50^{b} \pm 1.50$	$6.25^{b} \pm 0.50$	$6.55^{b} \pm 0.50$
PSG_3	$6.00^{b} \pm 1.00$	$6.10^{c} \pm 3.00$	$6.40^{b} \pm 3.00$	$6.00^{c} \pm 0.30$	$6.00^{b} \pm 1.0$	$5.65^{b} \pm 2.00$	$6.05^{b} \pm 1.00$
PSG_4	$6.30^{b} \pm 0.50$	$7.15^{b} \pm 1.00$	$7.15^{a} \pm 2.00$	$6.60^{a} \pm 1.30$	$6.25^{b} \pm 0.50$	$5.95^{b} \pm 1.00$	$6.50^{b} \pm 2.00$
PSG_5	$7.00^{a} \pm 0.00$	$6.65^{b} \pm 2.50$	$6.75^{b} \pm 2.00$	$6.65^{a} \pm 1.00$	$7.30^{a} \pm 0.50$	$6.75^{a} \pm 2.00$	$7.00^{a} \pm 1.00$
C	$5.75^{d} \pm 0.50$	$5.65^{b} \pm 1.00$	$5.60^{c} \pm 1.00$	$5.10^{d} \pm 1.50$	$6.35^{b} \pm 1.50$	$5.45^{c} \pm 1.50$	$5.55^{c} \pm 1.50$
CSG_1	$6.10^{c} \pm 0.60$	$5.80^{b} \pm 1.50$	$5.90^{c} \pm 1.00$	$5.15^{d} \pm 1.00$	$5.90^{c} \pm 1.00$	$5.55^{c} \pm 1.00$	$6.05^{c} \pm 1.00$
CSG_2	$6.20^{c} \pm 0.50$	$6.20^{b} \pm 0.50$	$6.05^{a} \pm 0.00$	$5.95^{b} \pm 0.50$	$6.20^{c} \pm 0.50$	$5.45^{c} \pm 0.50$	$6.30^{b} \pm 0.50$
CSG_3	$6.25^{c} \pm 0.50$	$5.90^{b} \pm 0.50$	$5.60^{e} \pm 0.50$	$6.25^{a} \pm 1.00$	$6.20^{c} \pm 2.00$	$6.10^{b} \pm 1.00$	$6.50^{b} \pm 1.00$
CSG_4	$6.90^{a} \pm 1.00$	$5.85^{b} \pm 0.50$	$5.80^{c} \pm 1.50$	$6.15^{b} \pm 2.00$	$6.40^{c} \pm 1.50$	$6.05^{b} \pm 1.00$	$6.55^{b} \pm 1.00$
CSG_5	$6.80^{b} \pm 1.00$	$5.10^{b} \pm 1.00$	$6.25^{c} \pm 1.00$	$7.00^{a} \pm 1.50$	$7.55^{a} \pm 0.00$	$7.05^{a} \pm 0.00$	$7.10^{a} \pm 0.00$

Values are mean of duplicate samples ± standard deviation
Means having different superscript in the same column are significantly different ($p \leq 0.05$).

Total available carbohydrate ranged from 60.14% to 84.22% with sample MSG_5 (70%M; 25%S; 5%G) as the lowest and sample P (100% Sweet potato) as the highest. This is in line with the findings of Richard *et al*, [21] who reported 86.20% to 89.71% carbohydrate. Carbohydrate is the major nutrient component of yellow cassava, sweet potato and maize. However there was significant difference ($p \leq 0.05$) in the chemical composition of the starches.

Amylose content ranged from 21.06% to 29.25% with sample CSG_5 (70%C; 25%S; 5%G) as the lowest and sample M (100% M; Control) as the highest. This finding falls within the range reported by Richard *et al,* [21] of 13.60% to 35.80% in cassava starch. Amylose content decreased with an increase in the level of protein substitution. Amylose is the linear components of starch that imparts definite characteristics to starch and therefore its content is an important criterion for determining starch quality [22].

Amylopectin ranged from 71.02% to 78.94% with sample C (100% Yellow cassava) as the lowest and sample CSG_5 (70%C; 25%S; 5%G) as the highest. Amylopectin increased with an increase in protein substitution. The amylopectin content is in line with the findings of Eke-Ejiofor and Owuno [18] who reported a range of 66.27% to 76.79% for sweet potato starch.

Sugar content ranged from 2.49% to 4.95% with sample C (100% Yellow cassava) as the lowest and sample CSG_3 (80%C; 15%S; 5%G) as the highest, while starch content ranged from 56.57% to 70.15% with sample PSG_3 (80%P; 15%S; 5%G) as the lowest and sample M (100% Maize) as the highest. Starch content in the present study is slightly higher than the findings of Eke-Ejiofor and Owuno [18] who reported a range of 58.72% to 68.85% for wheat/three-leaf yam composite flour blend.

3.3. Functional Properties of Starch Blends

Table 3, shows the functional properties of starch blends. Dispersibility ranged from 70.00% to 81.25% with sample MSG_2 (85%M; 10%; 5%G) as the least dispersed and sample M (100% M; Control) as the most dispersed sample. The results obtained from the study indicated that there were significant differences ($P \leq 0.05$) in the dispersibility of the starch blends. The dispersibility of sample C (100% Yellow cassava) at 81.25% was significantly higher than sample P (100% Sweet potato) at 79.00%. This is in agreement with the findings of Eke-Ejiofor and Owuno [23] who reported a value of 84% to 86% for cassava and sweet potato starches respectively. Kulkarni *et al [11]* reported that the higher the dispersibility, the better the starch reconstitutes in water to give a fine and consistent paste. Therefore, sample C (100% Yellow cassava) was the best starch in terms of dispersibility.

Table 2. Chemical Composition (%) of Gruel Blends from Maize, Yellow Cassava or Sweet Potato Starches with Defatted Soybean and Groundnut Flour

Sample	Moisture	Fat	Protein	Ash	Amylose	Amylopectin	Carbohydrate	Sugar	Starch
M(con)	$10.85^{d} \pm 0.05$	$6.69^{c} \pm 0.35$	$5.46^{j} \pm 0.00$	$0.09^{o} \pm 0.00$	$29.25^{a} \pm 0.04$	$70.75^{f} \pm 0.04$	$76.91^{d} \pm 0.40$	$3.00^{d} \pm 0.04$	$70.15^{a} \pm 0.07$
MSG_1	$10.40^{d} \pm 0.20$	$7.52^{b} \pm 0.39$	$6.34^{h} \pm 0.84$	$0.69^{e} \pm 0.11$	$26.10^{c} \pm 0.04$	$73.90^{d} \pm 0.04$	$75.06^{d} \pm 0.53$	$3.97^{b} \pm 0.03$	$64.45^{c} \pm 0.52$
MSG_2	$10.25^{e} \pm 0.15$	$7.91^{a} \pm 0.40$	$14.27^{d} \pm 1.72$	$0.35^{f} \pm 0.05$	$25.08^{d} \pm 0.04$	$74.92^{c} \pm 0.04$	$67.19^{g} \pm 2.35$	$3.26^{c} \pm 0.04$	$69.49^{a} \pm 0.04$
MSG_3	$9.75^{e} \pm 0.25$	$8.33^{a} \pm 0.23$	$16.15^{b} \pm 0.01$	$0.80^{e} \pm 0.10$	$26.06^{c} \pm 0.00$	$73.04^{e} \pm 0.00$	$64.98^{g} \pm 0.38$	$3.17^{c} \pm 0.06$	$68.89^{a} \pm 0.04$
MSG_4	$9.75^{e} \pm 0.15$	$8.19^{a} \pm 0.22$	$12.57^{e} \pm 0.00$	$0.98^{d} \pm 0.10$	$24.84^{d} \pm 0.04$	$75.16^{c} \pm 0.04$	$68.46^{e} \pm 0.33$	$3.29^{c} \pm 0.03$	$66.68^{b} \pm 0.53$
MSG_5	$9.50^{f} \pm 0.10$	$8.93^{a} \pm 0.20$	$20.43^{a} \pm 0.85$	$0.99^{d} \pm 0.01$	$25.16^{d} + 0.04$	$74.84^{c} \pm 0.04$	$60.14^{f} \pm 0.57$	$4.81^{a} \pm 0.00$	$68.11^{a} \pm 0.13$
P	$12.90^{a} \pm 0.00$	$0.29^{g} \pm 0.10$	$2.25^{l} \pm 0.00$	$0.35^{f} \pm 0.05$	$28.90^{a} \pm 0.08$	$71.10^{f} \pm 0.08$	$84.11^{a} \pm 0.15$	$2.48^{e} \pm 0.01$	$61.34^{c} \pm 0.51$
PSG_1	$12.10^{c} \pm 0.20$	$2.27^{f} \pm 0.08$	$4.65^{k} \pm 0.85$	$0.39^{e} \pm 0.09$	$27.01^{b} \pm 0.08$	$72.99^{e} \pm 0.08$	$79.58^{h} \pm 0.06$	$2.99^{d} \pm 0.03$	$66.57^{b} \pm 0.15$
PSG_2	$11.70^{c} \pm 0.30$	$2.58^{e} \pm 0.21$	$5.68^{j} \pm 0.00$	$0.25^{g} \pm 0.05$	$25.08^{d} \pm 0.04$	$74.92^{c} \pm 0.04$	$79.82^{a} \pm 0.03$	$2.67^{d} \pm 0.04$	$63.94^{c} \pm 0.01$
PSG_3	$11.70^{c} \pm 0.10$	$2.86^{e} \pm 0.68$	$11.98^{f} \pm 0.43$	$0.99^{d} \pm 0.10$	$25.67^{c} \pm 0.08$	$74.33^{d} \pm 0.08$	$72.48^{e} \pm 0.10$	$2.93^{d} \pm 0.03$	$56.57^{d} \pm 0.03$
PSG_4	$11.15^{d} \pm 0.15$	$4.15^{d} \pm 0.40$	$13.41^{e} \pm 0.86$	$0.88^{e} \pm 0.10$	$27.05^{b} \pm 0.04$	$72.95^{e} \pm 0.04$	$70.56^{f} \pm 1.01$	$4.35^{a} \pm 0.02$	$65.25^{c} \pm 0.28$
PSG_5	$11.20^{d} \pm 5.15$	$4.48^{d} \pm 0.34$	$14.95^{c} \pm 0.85$	$1.05^{c} \pm 0.05$	$23.58^{e} \pm 0.12$	$76.42^{b} \pm 0.12$	$68.33^{f} \pm 0.37$	$3.46^{b} \pm 0.04$	$68.27^{a} \pm 0.14$
C	$13.65^{a} \pm 0.15$	$1.57^{f} \pm 0.18$	$0.50^{l} \pm 0.00$	$0.34^{f} \pm 0.05$	$28.98^{a} \pm 0.08$	$71.02^{f} \pm 0.08$	$83.93^{a} \pm 0.28$	$2.49^{e} \pm 0.05$	$59.68^{d} \pm 0.20$
CSG_1	$14.15^{a} \pm 0.05$	$2.49^{f} \pm 0.49$	$4.00^{l} \pm 0.00$	$0.78^{e} \pm 0.11$	$24.25^{e} \pm 0.00$	$75.75^{b} \pm 0.00$	$78.39^{c} \pm 0.64$	$4.57^{a} \pm 0.05$	$64.32^{c} \pm 0.31$
CSG_2	$12.93^{a} \pm 0.05$	$3.66^{d} \pm 0.34$	$5.77^{i} \pm 0.01$	$1.02^{o} \pm 0.04$	$23.94^{e} \pm 0.08$	$76.06^{b} \pm 0.08$	$76.67^{d} \pm 0.42$	$3.32^{c} \pm 0.04$	$59.64^{d} \pm 0.60$
CSG_3	$12.25^{b} \pm 0.05$	$4.10^{d} \pm 0.60$	$10.55^{g} \pm 0.05$	$0.15^{g} \pm 0.05$	$22.64^{e} \pm 0.12$	$77.36^{a} \pm 0.12$	$72.96^{e} \pm 0.50$	$4.95^{a} \pm 0.00$	$64.55^{c} \pm 0.21$
CSG_4	$12.20^{b} \pm 0.20$	$4.98^{d} \pm 0.01$	$8.92^{g} \pm 0.02$	$1.24^{a} \pm 0.16$	$21.26^{f} \pm 0.08$	$78.74^{a} \pm 0.08$	$72.65^{e} \pm 0.05$	$4.27^{a} \pm 0.04$	$67.82^{a} \pm 0.37$
CSG_5	$11.90^{c} \pm 0.30$	$6.34^{c} \pm 0.24$	$4.71^{k} \pm 0.88$	$1.14^{c} \pm 0.05$	$21.06^{f} \pm 0.02$	$78.94^{a} \pm 0.02$	$75.70^{d} \pm 0.90$	$4.72^{a} \pm 0.02$	$66.57^{b} \pm 0.53$

Values are mean of duplicate samples ± standard deviation
Means having different superscript in the same column are significantly different ($p \leq 0.05$).

Relative bulk density ranged from 0.31g/ml in sample CSG_5 (70M; 25%S; 5%G) as the lowest and 0.53g/ml in sample PSG_3 (80%P; 15%S; 5%G) as the highest. Relative bulk density results in the present study showed significant differences (p≤0.05) amongst the samples. Akubor and Obiegbuna [24] reported that bulk density of a sample could be used in determining its packaging requirements as this relates to the load the sample can carry if allowed to rest directly on one another. Results of the present study showed that cassava (0.34g/ml) had less relative bulk density than maize (0.45g/ml). The bulk densities decreased with increase in the protein sources. The reduction in bulk densities has nutritional implications as more can be eaten resulting in high energy and nutrient densities. This reduction is consistent with the report of Nnam [25]. Decrease in relative bulk density will help in reducing transportation and packaging cost.

Swelling power ranged from 6.02% to 8.29% with sample PSG_2 (85%P; 10%S 5%G) as the least and sample CSG_1 (90%C; 5%S; 5%G) as the highest, with significant difference (p≤0.05) amongst the samples. Swelling power determines the extent to which a starch based sample increase in volume when soaked in water in relation to its initial volume. Moorthy and Ramanujam [26] reported that the swelling power of flour granules is an indication of the extent of associative forces within the granule. Swelling power is also related to the water absorption index of the starch during heating [27]. The major factor that controls the swelling behavior of a starch is the strength and character of the micellar network within the granule [28]. Maize and cassava blends had a higher swelling power than sweet potato starch. The results have shown that dispersibility, bulk density and swelling power decreased with an increase in the level of protein substitution.

Solubility ranged from 1.30% to 14.39% with sample M (100% M; Control) as the lowest and sample CSG_3 (80%C; 15%S; 5%G) as the highest, showing significant difference (P≤0.05) which is in agreement with the findings of Eke-Ejiofor and Owuno [18] who reported a solubility value of 12.64% to 13.73% for wheat/three leaf yam starches and Eke-Ejiofor and Owuno [23] 13.00% to 14.00% for cassava and potato starches respectively. Solubility result in this study showed an increase as protein substitution increased. Solubility reflects the extent of intermolecular cross bonding with the granule [29].

Water absorption capacity ranged from 0.77g/ml to 2.16g/ml with samples PSG_2 (85%P, 10%S; 5%G), PSG_4 (75%P, 20%S; 5%) as the least and MSG_2 (85%M; 10%; 5%) as the most. Water absorption capacity is the ability of a product to incorporate water and water inhibition is an important functional trait in a food such as gruel [30]. The values ranged from 0.77 to 2.19g/g. There was significant difference (p≤0.05) between the various blends. The maize blends showed a higher water absorption capacity than the other blends. This may be attributed to variations in their starch sources and size of granules.

Least gelation values ranged from 4% to 8%. Least gelation concentration can be described as a measure of the minimum amount of starch or blends of starch that is needed to form gel in a given volume of water [31]. Samples with lower least gelation concentrations have a greater gelling capacity than those with higher least gelation concentrations [32]. The control, sample M (100% maize) had the least gelation concentration and hence the greater gelling capacity. Variations in gelling properties have been attributed to the increase in protein substitutes.

Table 3. Functional Properties of Gruel Blends from Maize, Yellow Cassava or Sweet Potato starch with Defatted Soybean and Groundnut Flour (%)

Sample	Dispersibility(%)	Bulk Density g/ml	Swelling Power	Solubility (%)	Water Absorption Capacity g/g	Least gelation concentration
M(control)	$74.00^e \pm 0.50$	$0.45^c \pm 0.03$	$7.17^e \pm 0.33$	$1.30^i \pm 0.31$	$1.14^e \pm 0.04$	$4.00^c \pm 0.00$
MSG_1	$70.50^f \pm 0.50$	$0.45^c \pm 0.03$	$7.01^f \pm 0.08$	$1.46^i \pm 0.38$	$1.53^c \pm 0.02$	$4.00^c \pm 0.00$
MSG_2	$70.00^f \pm 1.00$	$0.44^c \pm 0.00$	$6.04^g \pm 0.39$	$2.46^h \pm 0.50$	$2.16^a \pm 0.18$	$6.00^b \pm 0.00$
MSG_3	$69.80^f \pm 1.00$	$0.46^c \pm 0.01$	$7.26^e \pm 0.24$	$2.09^i \pm 0.39$	$1.78^b \pm 0.19$	$4.00^c \pm 0.00$
MSG_4	$73.50^e \pm 0.50$	$0.43^d \pm 0.00$	$7.05^f \pm 0.03$	$2.33^h \pm 0.16$	$1.02^e \pm 0.03$	$8.00^a \pm 0.00$
MSG_5	$71.00^e \pm 1.00$	$0.41^e \pm 0.02$	$6.72^g \pm 0.02$	$2.94^g \pm 0.09$	$0.28^d \pm 0.21$	$8.00^a \pm 0.00$
P	$79.00^c \pm 1.00$	$0.41^e \pm 0.01$	$6.70^g \pm 0.35$	$2.01^i \pm 0.30$	$0.79^f \pm 0.00$	$8.00^a \pm 0.00$
PSG_1	$79.00^c \pm 1.00$	$0.38^f \pm 0.03$	$8.30^b \pm 0.16$	$2.84^h \pm 0.05$	$0.78^f \pm 0.03$	$6.00^b \pm 0.00$
PSG_2	$80.25^b \pm 0.25$	$0.41^e \pm 0.02$	$6.62^g \pm 0.11$	$2.97^g \pm 0.02$	$0.77^f \pm 0.01$	$4.00^c \pm 0.00$
PSG_3	$78.50^c \pm 0.50$	$0.48^b \pm 0.07$	$7.85^c \pm 0.60$	$2.68^h \pm 0.18$	$0.79^f \pm 0.01$	$6.00^b \pm 0.00$
PSG_4	$79.00^d \pm 1.00$	$0.36^g \pm 0.01$	$7.74^d \pm 0.89$	$3.65^f \pm 0.01$	$0.77^f \pm 0.02$	$8.00^a \pm 0.00$
PSG_5	$78.50^c \pm 1.00$	$0.33^g \pm 0.02$	$7.36^e \pm 0.31$	$2.33^h \pm 0.24$	$0.79^f \pm 0.01$	$8.00^a \pm 0.00$
C	$81.25^a \pm 0.50$	$0.34^g \pm 0.04$	$7.02^f \pm 0.05$	$5.15^e \pm 0.23$	$1.59^c \pm 0.00$	$6.00^b \pm 0.00$
CSG_1	$80.25^b \pm 0.25$	$0.33^g \pm 0.02$	$7.29^a \pm 0.37$	$2.58^h \pm 0.10$	$1.15^e \pm 0.37$	$8.00^a \pm 0.00$
CSG_2	$79.50^c \pm 0.50$	$0.41^e \pm 0.01$	$7.24^e \pm 0.14$	$8.95^d \pm 0.48$	$1.53^c \pm 0.35$	$8.00^a \pm 0.00$
CSG_3	$79.25^c \pm 0.25$	$0.53^a \pm 0.06$	$7.44^e \pm 0.01$	$14.39^a \pm 1.34$	$1.11^e \pm 0.07$	$8.00^a \pm 0.00$
CSG_4	$73.50^e \pm 0.50$	$0.41^e \pm 0.03$	$6.11^g \pm 0.35$	$13.67^a \pm 1.17$	$1.17^e \pm 0.03$	$6.00^b \pm 0.00$
CSG_5	$76.25^d \pm 0.25$	$0.31^g \pm 0.01$	$6.77^g \pm 0.08$	$10.64^b \pm 0.54$	$1.18^d \pm 0.01$	$6.00^b \pm 0.00$

Values are mean of duplicate samples ± standard deviation
Means having different superscript in the same column are significantly different (p ≤ 0.05).

Table 4. Pasting Properties of Gruel Blends from Maize, Yellow Cassava or Sweet Potato Starches with Defatted Soybean and Groundnut Flours

Sample	Peak viscosity (RVU)	Trough viscosity (RVU)	Breakdown (RVU)	Final Viscosity (RVU)	Setback visity(RVU)	Peak time Min	Pasting Temperature °C
M(control)	$316.19^{e} \pm 0.49$	$143.14^{f} \pm 0.47$	$174.05^{e} \pm 0.05$	$256.51^{b} \pm 0.42$	$113.25^{a} \pm 1.00$	$4.61^{a} \pm 0.01$	$75.04^{b} \pm 0.02$
MSG$_1$	$249.96^{f} \pm 0.04$	$111.38^{g} \pm 1.30$	$137.82^{f} \pm 0.02$	$208.91^{d} \pm 0.01$	$95.92^{b} \pm 0.92$	$4.61^{a} \pm 0.01$	$75.33^{b} \pm 0.53$
MSG$_2$	$230.59^{f} \pm 0.59$	$102.50^{h} \pm 0.50$	$128.59^{f} \pm 0.59$	$196.59^{d} \pm 0.42$	$94.59^{b} \pm 0.42$	$4.53^{a} \pm 0.01$	$75.95^{b} \pm 0.05$
MSG$_3$	$194.39^{g} \pm 0.55$	$100.96^{h} \pm 0.04$	$93.21^{g} \pm 0.21$	$175.88^{f} \pm 0.13$	$74.92^{c} \pm 0.09$	$4.52^{a} \pm 0.02$	$75.90^{b} \pm 0.10$
MSG$_4$	$190.96^{g} \pm 0.04$	$96.93^{h} \pm 0.10$	$94.00^{g} \pm 0.09$	$174.04^{f} \pm 0.22$	$77.05^{c} \pm 0.38$	$4.52^{a} \pm 0.02$	$75.95^{b} \pm 0.10$
MSG$_5$	$158.18^{g} \pm 0.40$	$92.90^{h} \pm 0.85$	$63.43^{i} \pm 1.40$	$157.00^{g} \pm 1.00$	$63.77^{d} \pm 0.49$	$4.52^{a} \pm 0.02$	$77.25^{b} \pm 0.50$
P	$581.37^{a} \pm 1.30$	$241.48^{a} \pm 0.85$	$341.28^{b} \pm 0.95$	$310.72^{a} \pm 0.70$	$69.54^{c} \pm 0.46$	$4.44^{a} \pm 0.04$	$71.35^{c} \pm 0.50$
PSG$_1$	$412.00^{c} \pm 2.00$	$190.57^{c} \pm 0.84$	$223.17^{d} \pm 0.50$	$267.92^{b} \pm 0.50$	$78.03^{c} \pm 0.05$	$4.52^{a} \pm 0.02$	$81.21^{a} \pm 0.51$
PSG$_2$	$356.17^{d} \pm 0.50$	$174.34^{d} \pm 0.34$	$180.62^{e} \pm 0.39$	$245.17^{b} \pm 0.17$	$70.22^{c} \pm 0.46$	$4.57^{a} \pm 0.04$	$79.90^{a} \pm 0.90$
PSG$_3$	$326.49^{e} \pm 1.01$	$166.84^{e} \pm 0.17$	$161.83^{e} \pm 1.00$	$231.09^{c} \pm 1.09$	$65.89^{d} \pm 0.39$	$4.57^{a} \pm 0.04$	$79.88^{a} \pm 0.88$
PSG$_4$	$321.32^{e} \pm 0.51$	$165.59^{e} \pm 0.42$	$157.69^{f} \pm 1.02$	$222.92^{c} \pm 0.34$	$64.97^{d} \pm 0.11$	$4.57^{a} \pm 0.04$	$80.78^{a} \pm 0.78$
PSG$_5$	$278.84^{f} \pm 0.84$	$149.75^{f} \pm 0.25$	$129.68^{f} \pm 0.50$	$211.42^{d} \pm 1.42$	$63.67^{d} \pm 0.34$	$4.57^{a} \pm 0.04$	$80.50^{a} \pm 0.50$
C	$620.54^{a} \pm 0.54$	$200.71^{b} \pm 0.63$	$419.38^{a} \pm 0.38$	$263.00^{b} \pm 0.58$	$60.54^{e} \pm 0.54$	$3.55^{b} \pm 0.05$	$71.59^{c} \pm 0.31$
CSG$_1$	$481.00^{b} \pm 1.00$	$171.72^{d} \pm 1.45$	$308.46^{b} \pm 0.38$	$222.83^{c} \pm 5.00$	$50.87^{g} \pm 0.80$	$3.67^{b} \pm 0.07$	$71.59^{c} \pm 0.31$
CSG$_2$	$453.37^{b} \pm 0.70$	$171.18^{d} \pm 0.85$	$283.33^{c} \pm 1.00$	$221.81^{c} \pm 1.06$	$50.12^{g} \pm 0.30$	$3.70^{b} \pm 0.10$	$72.04^{c} \pm 0.14$
CSG$_3$	$431.69^{b} \pm 2.02$	$156.08^{f} \pm 100$	$275.22^{c} \pm 0.55$	$215.25^{d} \pm 0.50$	$61.34^{e} \pm 0.67$	$3.70^{b} \pm 0.10$	$92.37^{c} \pm 0.52$
CSG$_4$	$350.97^{d} \pm 0.95$	$128.67^{g} \pm 0.50$	$223.75^{d} \pm 1.00$	$183.25^{e} \pm 1.00$	$52.04^{f} \pm 1.04$	$3.67^{b} \pm 0.07$	$72.04^{c} \pm 0.14$
CSG$_5$	$329.10^{e} \pm 1.60$	$121.92^{g} \pm 1.00$	$206.22^{d} \pm 0.36$	$175.75^{f} \pm 0.10$	$53.33^{f} \pm 1.00$	$3.70^{b} \pm 0.10$	$70.94^{c} \pm 0.86$

Values are mean of duplicate samples± standard deviation
Means having different superscript in the same column are significantly different ($p < 0.05$).

3.4. Pasting Properties of Food Blends (Gruel)

Pasting properties are functional properties relating to the ability of an item to act in a paste-like manner [33]. According to Wang *et al,* [34], starch granules when heated become hydrated, swell and are transformed into a paste. The granule structure collapses due to melting of crystallites, unwinding of double helices and breaking of hydrogen bonds.

Table 4: Shows the pasting properties of the blends produced from maize, yellow cassava or sweet potato starches; defatted soybean and groundnut flours such as peak, trough, breakdown, final and setback viscosities, pasting time and pasting temperature.

Peak and trough viscosities ranged from 158.18RVU to 620.00RVU with sample MSG$_5$ (70%M; 25%S; 5%G) as the lowest and sample C (100% Yellow cassava) as the highest respectively. The peak viscosity is the maximum viscosity attained by gelatinized starch during heating in water. Sample C (100% yellow cassava) had the highest while sample MSG$_5$ (75%M, 25%S and 5%G) had the lowest values. This result is in agreement with the findings of Ojo *et al,* [35]. The peak viscosity has been reported to be closely associated with the degree of starch damage. High peak viscosity values are indicative of higher starch granule damage and starch binding capacity of the granules [36,37]. High peak viscosity is an indication of the solubility of the blends for products requiring high gel strength and elasticity. Higher peak viscosity values correlate increased solubility in this study.

Trough viscosity is the minimum viscosity value which measures the ability of paste to withstand breakdown during cooling. Result of trough viscosity ranged from 92.90RVU to 241.48RVU for MSG$_5$ (70%M; 25%S; 5%G) and sample P (100% Sweet potato) respectively.

Breakdown viscosity ranged from 63.43RVU to 419.38RVU with sample MSG$_5$ (70%M; 25%S; 5%G) as the lowest and sample C (100% Yellow cassava) as the highest. The value of breakdown viscosity which is the measure of the susceptibility of the cooked starch sample to disintegration were significantly different ($p \leq 0.05$) and ranged between 63.43RVU for MSG$_5$ (70%M; 25%S; 5%G) to 419.38RVU for sample C (100% Yellow cassava). The high values recorded support the fact that high peak viscosities are associated with higher breakdown viscosity [36]. In agreement with the above finding, Adebowale *et al,* [38] reported that the higher the breakdown viscosity, the lower the ability of the sample to withstand heating and shear stress during cooking. Hence, sample C (100% yellow cassava) might not be able to withstand heating and shear stress when compared to the control and the other samples.

Final viscosity ranged from 157.00RVU to 310.72RVU. During cooling, re-association between starch molecules especially amylose will result in the formation of a gel structure and the viscosity then increases to a final viscosity [39]. It is the most commonly used parameter to determine the quality of a starch based sample. It gives an idea of the ability of the product to gel after cooking. The final viscosity of sample P (100% Sweet potato) at 310.72RVU was the highest and the lowest at 157.00RVU for sample MSG$_5$ (70%M; 25%S; 5%G). It indicates the ability to form a gel after cooling [40].

Setback viscosity ranged from 50.12RVU to 113.25RVU with sample CSG$_2$ (85%C; 10%S; 5%G) as the lowest and sample M (100% M; Control) as the highest. Higher setbacks results in lower retro-gradation during cooling of products [40]. Starch retro-gradation is usually accompanied by a series of physical changes such as increased viscosity and turbidity of pastes, gel formation, exudation of water [41].

Pasting time ranged from 3.55 to 4.61min with sample C (100% Yellow cassava) as the lowest and sample M (100% M; Control) and MSG_1 (90%M; 5%S; 5%G) as the highest, while pasting temperature ranged from 70.94°C to 90.37°C with sample CSG_5 (70%C; 25%S; 5%G) as the lowest and sample CSG_3 (80%C; 15%S; 5%G) as the highest. Pasting time is the measure of the cooking time [38], while the pasting temperature is a measure of the minimum temperature required to cook a sample.

4. Conclusion

The findings of this study has shown clear potential for the production of substitute gruel from yellow cassava or sweet potato starch with blends of defatted soybean and groundnut flours as a replacement for maize and animal protein respectively. The gruels were nutritionally acceptable though in varying degrees, based on the functional, chemical and sensory attributes of the blends as the blends contained higher fat, ash and protein. It was concluded that supplementation level up to 25% for defatted soybean and 5% for defatted groundnut flour gave the best product as well as acceptability to consumers.

KEYS

M (Control) = 100% Maize

MSG_1 = 90% Maize; 5% Defatted Soybean; 5% Defatted Groundnut

MSG_2 = 85% Maize; 10% Defatted Soybean; 5% Defatted Groundnut

MSG_3 = 80% Maize; 15% Defatted Soybean; 5% Defatted Groundnut

MSG_4 = 75% Maize; 20% Defatted Soybean; 5% Defatted Groundnut

MSG_5 = 70% Maize; 25% Defatted Soybean; 5% Defatted Groundnut

P = 100% Sweet Potato

PSG_1 = 90% Sweet Potato; 5% Defatted Soybean; 5% Defatted Groundnut

PSG_2 = 85% Sweet Potato; 10% Defatted Soybean; 5% Defatted Groundnut

PSG_3 = 80% Sweet Potato; 15% Defatted Soybean; 5% Defatted Groundnut

PSG_4 = 75% Sweet Potato; 20% Defatted Soybean; 5% Defatted Groundnut

PSG_5 = 70% Sweet Potato; 25% Defatted Soybean; 5% Defatted Groundnut

C= 100% Yellow Cassava

CSG_1 = 90% Yellow Cassava; 5% Defatted Soybean; 5% Defatted Groundnut

CSG_2 =85% Yellow Cassava; 10% Defatted Soybean; 5% Defatted Groundnut

CSG_3 = 80% Yellow Cassava; 15% Defatted Soybean; 5% Defatted Groundnut

CSG_4 = 75% Yellow Cassava; 20% Defatted Soybean; 5% Defatted Groundnut

CSG_5 = 70% Yellow Cassava; 25% Defatted Soybean; 5% Defatted Groundnut

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