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Effect of Processing Treatments on the Proximate, Functional and Sensory Properties of Soy-Sorghum-Roselle Complementary Food

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Authors' contributions

This work was carried out in collaboration between all authors. Author OEA designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript and managed literature searches. Authors DEJ, KOA, UEU, OAA and JAI managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aim: The objective of this work was to produce complementary foods from germinated/fermented sorghum, germinated/roasted soybean and dried roselle calyces.
Methodology: Complementary foods were formulated from sorghum, soybean and roselle calyces by varying the processing methods (fermentation, germination and roasting) applied to them. Proximate, functional, colour and sensory properties of the complementary foods were determined.
Results: The protein contents for the seven formulations were significantly different ($p \leq 0.05$) from each other. The sample consisting of sorghum flour, germinated soybean and roselle flour (SFGS) had the highest protein content followed by the sample made from germinated sorghum, germinated soybean and roselle flour (GSGS). The ash content ranged from 2.00% to 4.50%. Fat content ranged from 4.95% to 16.35%. Fat was significantly different for all the formulations. FSRS

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made from fermented sorghum and roasted soybean, had the highest fat content followed by SF. The moisture content of the formulations ranged from 6.28-10.75%. From the values obtained, there were significant differences ($p \leq 0.05$) in the water absorption capacity, oil absorption capacity, loosed and packed bulk density as well as swelling capacity among the samples. Swelling capacity (SC) values ranged between 2.60% for GSRS and 6.95% for SF. Water absorption capacity (WAC) of the flour mixes ranged from 1.20 ml/g to 2.40 ml/g for FSRS and SFGS respectively. The values for oil absorption capacity (OAC) were between 0.84 mL/g for SFRS and 1.67 mL/g for SFGS. From the result obtained, there was significant difference ($P \leq 0.05$) in loosed and packed density of the complementary foods. Packed bulk density (PBD) was between 0.71 g/cm^3 for FSRS and 0.86g/cm^3 for SF. The samples varied significantly ($P \leq 0.05$) from one another in all the colour parameters evaluated. FSGS and FSRS scored highest in L* (64.14 and 59.44 respectively), a* (12.06 and 11.23 respectively) and b* (17.88 and 14.18 respectively). There were significant differences ($p \leq 0.05$) among the complementary foods in colour, aroma, and taste, while there were no significant difference ($p \geq 0.05$) among them in mouthfeel and overall acceptability.

Conclusion: The results from this study showed that processing methods employed had marked effect on the proximate, functional and sensory properties of the complementary foods produced from soybean, sorghum and roselle calyces.

Keywords: Complementary food; processing; roselle; sorghum; soybean.

1. INTRODUCTION

In most developing countries, particularly in Africa and Asia, complementary foods are prepared locally from cereal grains which form part of the staple foods of the people [1]. Maize, sorghum, millet, rice and acha which are commonly used in Nigeria [1] are of low nutrient density and this has been engaging the attention of nutrition workers in several countries and international organizations [2]. Protein-energy malnutrition among children is the major health challenges in the developing countries [2,3] and this is as a result of inappropriate complementary feeding practices, low nutritional quality of traditional foods, high cost of quality protein-based foods [3], low income, poor sentimental conditions and lack of education [4]. In addition, few low-income countries have failed to adopt comprehensive complementary food policies and programmes which have been developed [5]. These programmes are based on local foods that are culturally acceptable, easily prepared and affordable by the majority [5].

Several works have been done to enhance the nutritional status of cereal grains with legumes which are known to be richer in protein, certain minerals and vitamins [6,4,3,7]. The use of cereal-legume based food has long been advocated as alternative protein and energy source for infant and young children [8]. It is evident that when cereals and legumes are judiciously selected and combined, a desirable pattern of essential amino acids of high biological value is obtained [9]. Cereals are rich in sulphur containing amino acids such as methionine and cystine while legumes are rich in essential amino acids such as lysine [3]. The nutrient density of complementary foods is also enhanced through addition of other food components that are rich in vitamins and minerals [9].

Processing of cereals and legumes such as soaking, fermentation, germination, roasting etc enhance their qualities [10]. Fermentation of grain legumes before its incorporation or the co-fermentation of both cereals and grain legumes has the advantage of solubilizing the material constituents as well as reducing or eliminating the anti-nutritional factors [11]. Germination is induced by rehydration of the seed, which increases both respiration and metabolic activity that allow the mobilization of primary and secondary metabolites [12] and improves the nutritional and functional qualities of sorghum by changing chemical compositions and eliminating antinutritional factors [13]. Roasting is done to impart desirable sensory qualities, enhance palatability and reduce anti nutritional factors [14]. Egounlety [15] evaluated the sensory and nutritional qualities of *tempeh*-fortified maize based complementary food and reported improved nutrient density which compared favourably with a commercial product (Cerelac). Ijarotimi and Keshinro [3] formulated an infant formula from germinated popcorn, bambara groundnut and African locust bean flour. This present work was carried to formulate complementary food from germinated/fermented sorghum, germinated/roasted soybean and roselle calyces.

2. MATERIALS AND METHODS

2.1 Sources of Materials

Sorghum (Red Sokoto), soybean (white cultivar), and fresh roselle calyces were purchased from Bodija market, Ibadan and were identified at the Department of Botany, University of Ibadan. The analyses were carried out at the Department of Food Technology and the Central Laboratories of University of Ibadan.

2.2 Sample Preparation

2.2.1 Preparation of germinated sorghum flour

Germination was carried out according to the method described by [16]. Sorghum grains were manually cleaned to remove husks, stone, cob, damaged and coloured seeds. These were achieved through winnowing, sieving and hand picking. The grains were washed in 5% (w/v) sodium chloride solution to suppress mould growth and soaked in tap water in ratio of 1:3 (w/v) grain for 12 h at room temperature (32±2ºC), the water drained at 4 hour interval after which the seed were drained and spread separately on a clean jute bag, covered with damp cotton and were allowed to germinate for 24 h. Water was sprinkled at 12 h interval to facilitate the germination process. At the end of germination, root hairs were removed from the germinated grains. Grains were dried at 60ºC in an oven to a moisture content of 10% and ground into flour using attrition mill (globe p44 China). Flour was passed through a 0.5 mm mesh size sieve. They were packaged in an air tight polyethylene bags, stored in plastic containers with lids and then stored in cool dry place from where samples were taken for analyses.

2.2.2 Preparation of fermented sorghum flour (*Ogi-baba*)

Fermented *Ogi-baba* was prepared using the improved method of [17] that gave higher protein recovery and better quality porridge. Sorghum was cleaned as described above sorted and steeped in tap water (1: 3 w/v) for 72 h. After decanting the steeping water, the sorghum was milled in a Premier Mill and wet-sieved (1:8 w/v) through a locally manufactured sieve (1 mm). The deposit was left to ferment for 12 h before decanting the water. The fresh *ogi* was dried at 60ºC for 24 h and milled and sieved using mesh size 100 mm. They were packaged in an air tight polyethylene bags, stored in plastic containers with lids and then stored in cool dry place from where samples were taken for analyses.

2.2.3 Preparation of sorghum flour

The procedure described by [15] was used. Sorghum was cleaned as described above, sorted, washed and dried at 60ºC for 24 h. Before double-milling in a hammer mill (Christy & Lab), sieved using 150 mm mesh size and stored as described above.

2.2.4 Preparation of roselle calyces flour

Fresh Roselle calyces were washed, dried at 50ºC for 5 hrs, milled and sieved using 100 mm mesh size [18]. The flour was packaged in an air tight polyethylene bag, stored in plastic container with lid and then stored in cool dry place from where samples were taken for analyses.

2.2.5 Preparation of germinated soybean flour

The method described by [3] was employed. The soybean seeds were cleaned as described above. Seeds were rinsed, soaked in deionized water (1:3, w/v) for 24 hr at ambient temperature (23–25ºC). Seeds were drained and placed on perforated aluminum pans lined with filter paper, then placed in a dark, temperature controlled cabinet at 30ºC for germination. The seeds germinated after 4 days and the seeds were washed with distilled water manually, oven dried at 60ºC (Plus11 Sanyo Gallenkamp PLC, UK) for 20 hours, milled using a Philips laboratory blender (HR2811 model) and sieved using a 60 mm mesh sieve (British Standard). The flour was stored at room temperature (27ºC) in a well sealed plastic container prior to analyses.

2.2.6 Preparation of roasted soybean flour

This was done according to the procedure described by [19]. Soybean seeds were cleaned as earlier discussed. The beans were soaked, dehulled and roasted for 4 minutes in a frying pan over a gas cooker flame (115ºC). The roasted beans were cooled, sorted to remove damaged ones, oven dried at 60ºC (Plus 11 Sanyo Gallenkamp PLC, UK) and milled using a Philips laboratory blender (HR2811 model).

2.3 Sample Formulation

Sample formulation was done based on the specification of a joint FAO/WHO/UNU committee that recommended minimum levels of 16.7%, 6.0% and 375 Kcal/100 g for protein, fat and energy respectively [15]. This was achieved using the Nutri Survey Linear Programming Package 2004 version. This is shown in Table 1.

2.4 Analysis of Samples

Proximate, functional, sensory and colour properties of the formulations were carried out using standards methods [20,21,3,22] respectively. The analysis of variance (ANOVA) was performed to determine significant differences between the means of proximate composition, colur, sensory attributes, pasting properties and functional properties while the means were separated using the new Duncan multiple range test at $p<0.05$. The means and standard deviations of the triplicate analyses of the samples were calculated. These were achieved using the Statistical Package for the Social Scientists (SPSS) version 17.0.

3. RESULTS AND DISCUSSION

3.1 Effect of Processing Treatments on the Proximate Composition of Soy-Sorghum Roselle Complementary Foods

The result of proximate composition of complementary foods and effect of different processing treatments like roasting, germination and fermentation is presented in Table 2. According to the result, there were significant differences ($p\leq0.05$) in the moisture content of the seven formulations. However, all the samples were within the normal moisture contents of dried food (flour blends), that is below 12.5% for shelf-stable storage [23]. It is believed that materials such as flour and starch containing more than 12.5% moisture have less storage stability than those with lower moisture content. For this reason, a water content of not more than 12.5% is generally specified for flours and other related products. The ash content ranged from 2.00% to 4.50%. These values are similar to the values reported from the production and evaluation of breakfast cereal-based porridge mixed with sesame and pigeon peas for adults [24] but higher than results of [25] from the production of legumes-fortified weaning food. Fat content ranged from 4.95% to 16.35%. Fat was significantly different for all the formulations. FSRS made from fermented sorghum and roasted soybean, had the highest fat content followed by SF. From the results, the differences were significant ($p\leq0.05$). Protein content ranged from 12.46% to 32.42%. The protein contents for the seven formulations were significantly different ($p\leq0.05$) from each other. SFGS had the highest protein content followed by GSGS. The protein contents of the formulations were significantly higher than the reported results of [25] for the nutritive value of protein-energy legume-fortified weaning for *ogi* and reported results of [24] who evaluated cereal-based porridge mixed with sesame and pigeon peas for adults and the result reported for *Binni* mix [26]. Ashawe [27] reported an increase in protein content (7.28%) and ash (3.58%) when yam flour was substituted with 40% cowpea flour while [28] reported an increase in protein content from 3.5% in the control (yam flour) to 19.7% for yam flour fortified with 40% soybeans flour. The moisture (7.17%), crude protein (12.46%), fat (9.90%), ash (2.00%), and carbohydrate (49.75%) of the raw sorghum (SF) that served as the control were comparable to values reported by [29]. The relative high protein content observed in samples produced with soybean flour substitution (32.42%, 30.81%, 29.16%, 29.18%, and 33% for GSGS, GSRS, FSGS, FSRS and SFGS respectively) compared to control with 100% sorghum flour (12.46%) could be as result of high protein content of soybean. Salunkhe et al. [30] reported protein content of soybean as high as 40.4%.

3.2 Effect of Processing Treatments on the Functional Properties of Soy-Sorghum Roselle Complementary Foods

The effect of processing methods on the functional properties of complementary foods is presented in Table 3. The functional properties of food proteins determine their behaviour in food systems during processing, storage, preparation and consumption [31]. These functional properties and the interaction of proteins with other components directly and indirectly affect processing applications, food quality and ultimate acceptance [31]. From the values obtained, there were significant differences ($p\leq0.05$) in the water absorption capacity, oil absorption capacity, loosed and packed bulk density as well as swelling capacity among the samples. Padmashree et al. [32] reported that polar amino acids of proteins had an affinity for water and denatured proteins bind less water. Fat binding capacity has been attributed to the physical entrapment of oil. This is important since fat improves taste, texture and mouth feel [33]. Swelling capacity (SC) values ranged between 2.60% for GSRS and 6.95% for SF. Complementary foods do not require high swelling index as the food would absorb more water and have less solid resulting in low nutrient density for the infant [31]. Samples with least swelling index are preferred for a complementary food thus GSRS with least swelling capacity value of 2.60% is preferred. Water absorption capacity (WAC) of the flour mixes ranged from 1.20 ml/g to 2.40 ml/g for FSRS and SFGS respectively. The WAC values followed the same trend as the swelling index. Both SC and WAC ultimately determine the sample consistency (that is solid, semi-solid or liquid). Flours with both high SC and WAC values hold large amounts of water during preparation into gruels and thus become voluminous with low energy and nutrient density [34]. FSRS with least WAC value would provide a more nutrient-dense food for an infant. The values for oil absorption capacity (OAC) were between 0.84 mL/g for SFRS and 1.67 mL/g for SFGS. From the result obtained, there was significant difference (P≤0.05) in loosed and packed density of the complementary foods. Packed bulk density (PBD) was between 0.71 g/cm^3 for FSRS and 0.86g/cm^3 for SF. The lower the bulk density value, the higher the amount of flour particles that can stay together and thus increasing energy content that could be derivable from such diets [35]. FSRS with lowest packed bulk density is preferable in this regard. The Loose Bulk Density (LBD) which is the lowest attainable density without compression was least for FSRS (0.38 g/cm^3) and highest for GSGS (0.51 g/cm^3) though the difference was slight. This low density values of the complementary food samples implies that more of the samples could be prepared using a small amount of water yet giving the desired energy nutrient density and semi-solid consistency which can easily be fed to an infant [36]. Observably from the results, soybean flour substitution reduced significantly (P≤0.05) the packed bulk density (PBD) and swelling capacity (SC) of the complementary foods.

3.3 Effect of Processing Treatments on Colour Parameters of Soy-Sorghum-Roselle Complementary Food

The results of colour parameters (L, a, b, hue angle, deltachrome and colour intensity) is shown in Table 4. The samples varied significantly (P≤ 0.05) from one another in all the colour parameters evaluated. FSGS and FSRS scored highest in L* (64.14 and 59.44 respectively), a* (12.06 and 11.23 respectively) and b* (17.88 and 14.18 respectively). High values obtained for these samples in L* could be due to the leaching of colour pigments of sorghum and soybean during soaking operation thus, making them whither [31]. GSGS, SFGS and SFRS had higher 'colour difference' (∆E) (38.91, 39.62 and 39.08 respectively) while FSGS had the least (30.76).

3.4 Effect of Processing Treatments on the Sensory Profile of Soy-Sorghum Roselle Complementary Foods

The effect of treatment methods (roasting, germination and fermentation) on the consumer acceptability of the complementary foods is presented in Table 5 above. There were significant differences (p≤0.05) among the complementary foods in colour, aroma, and taste, while there were no significant difference (p≥0.05) among them in mouthfeel and overall acceptability. Also, there was no significant difference (p≥0.05) between the control sample and others. The complementary foods from fermented sorghum and roasted soybean flour (FSRS) had significantly (p≤0.05) higher mean score in taste, mouthfeel and overall acceptability. This relatively higher mean score of the roasted soybean and fermented sorghum flour sample could be probably due to the roasted flavour and aroma imparted on soybean during roasting coupled with astringency and aromatic compounds conferred on the sorghum by the fermentation process. Controlled roasting of grains brings about development of desirable roasted aroma in foods, which are described as nutty, burnt and coffee like, due to the formation of pyrazine compounds that also reflects the extent of browning colour development in the product [37]. Also, fermentation imparts desirable flavors esters, ketones, aldehydes and aromatic compounds as well as characteristic astringency to products. The relatively lower mean sensory scores in colour, aroma, taste, and overall acceptability recorded in the sample with untreated sorghum and germinated soybean flour (SFGS) could be probably due to the slight bitter after taste observed in untreated sorghum and germinated soybean samples. Notably, roselle flour was equally distributed among the samples and could have affected the sensory profile of the all the samples similarly and therefore could not be responsible for the differences observed among the samples and treatment. Notably, the results show that all the samples were equally acceptable by the panelists.

Table 1. Formulation of soy-sorghum-roselle complementary foods

	Sample description						
	A(GSGS)	**B(GSRS)**	**C(FSGS)**	**D(FSRS)**	**E(SFGS)**	**F(SFRS)**	**G(SF)**
Ingredients							
Sorghum flour %	-	-	-	-	58.2	58.2	100
Germinated							
Sorghum flour %	58.2	58.2	-	-	-	-	-
Fermented							
Sorghum flour %	-	-	58.2	58.2	-	-	-
Germinated							
Soybean flour %	38.8	-	38.8	-	38.8	-	-
Roasted							
Soybean flour %	-	38.8	-	38.8	-	38.8	-
Roselle							
Calyces flour %	3	3	3	3	3	3	-

Key: GSGS (Germinated sorghum, germinated soybean and roselle flour), GSRS (Germinated sorghum, roasted soybean and roselle flour), FSGS (Fermented sorghum, germinated soybean and roselle flour), FSRS (Fermented sorghum, roasted soybean and roselle flour), SFGS (Sorghum flour, germinated soybean and roselle flour), SFRS (Sorghum flour, roasted soybean and roselle flour) SF (Sorghum Flour)

Table 2. Proximate composition of soy-sorghum-roselle food

Sample	Crude Fat (%)	Crude Protein (%)	Ash Content (%)	Moisture Content (%)	Carbohydrate (%)
GSGS	$7.00±0.02^{d}$	$32.42±0.01^{b}$	$4.00±0.02^{c}$	$6.83±0.01^{e}$	$49.75±0.02^{e}$
GSRS	$6.00±0.03^{e}$	$30.81±0.01^{c}$	$4.00±0.04^{c}$	$7.14±0.02^{cd}$	$52.05±0.04^{c}$
FSGS	$8.91±0.01^{c}$	$29.16±0.02^{d}$	$4.50±0.04^{b}$	$10.75±0.02^{a}$	$46.68±0.07^{f}$
FSRS	$16.35±0.02^{a}$	$29.18±0.02^{d}$	$2.00±0.02^{e}$	$10.52±0.02^{b}$	$41.95±0.04^{g}$
SFGS	$5.00±0.02^{f}$	$33.93±0.03^{a}$	$3.50±0.02^{d}$	$7.11±0.01^{d}$	$50.46±0.08^{d}$
SFRS	$4.95±0.05^{g}$	$24.58±0.02^{e}$	$5.00±0.04^{a}$	$6.28±0.01^{f}$	$59.19±0.02^{a}$
SF	$9.90±0.02^{b}$	$12.46±0.02^{f}$	$2.00±0.03^{e}$	$7.17±0.03^{c}$	$68.47±0.06^{b}$

Values are mean±starndard deviation of triplicate scores. Column means with different superscripts are significantly different at 5% probability level (P≤ 0.05). Key: Key: GSGS (Germinated sorghum, germinated soybean and roselle flour), GSRS (Germinated sorghum, roasted soybean and roselle flour), FSGS (Fermented sorghum, germinated soybean and roselle flour), FSRS (Fermented sorghum, roasted soybean and roselle flour), SFGS (Sorghum flour, germinated soybean and roselle flour), SFRS (Sorghum flour, roasted soybean and roselle flour) SF (Sorghum Flour)

Table 3. Functional properties of soy-sorghum-roselle complementary food

Sample	Water absorption capacity (ml/g)	Oil absorption capacity (ml/g)	Loosed bulk density (g/cm^3)	Packed bulk density (g/cm^3)	Swelling power (g/g)
GSGS	$1.70±0.01^{d}$	$1.30±0.01^{b}$	$0.51±0.01^{a}$	$0.79±0.01^{c}$	$3.03±0.01^{f}$
GSRS	$1.60±0.02^{e}$	$0.97±0.02^{d}$	$0.41±0.02^{b}$	$0.76±0.01^{d}$	$2.60±0.02^{g}$
FSGS	$1.70±0.01^{d}$	$1.01±0.02^{c}$	$0.40±0.02^{b}$	$0.75±0.01^{d}$	$5.56±0.02^{c}$
FSRS	$1.20±0.03^{f}$	$0.92±0.02^{e}$	$0.38±0.02^{b}$	$0.71±0.02^{e}$	$5.65±0.01^{b}$
SFGS	$2.40±0.01^{a}$	$1.67±0.03^{a}$	$0.39±0.02^{b}$	$0.83±0.03^{b}$	$4.97±0.02^{d}$
SFRS	$2.30±0.02^{b}$	$0.84±0.01^{f}$	$0.48±0.02^{a}$	$0.81±0.01^{bc}$	$4.78±0.01^{e}$
SF	$2.20±0.01^{c}$	$1.01±0.01^{c}$	$0.49±0.02^{a}$	$0.86±0.01^{a}$	$6.95±0.01^{a}$

Values are mean±starndard deviation of triplicate scores. Column means with different superscripts are significantly different at 5% probability level (P≤ 0.05). Key: Key: GSGS (Germinated sorghum, germinated soybean and roselle flour), GSRS (Germinated sorghum, roasted soybean and roselle flour), FSGS (Fermented sorghum, germinated soybean and roselle flour), FSRS (Fermented sorghum, roasted soybean and roselle flour), SFGS (Sorghum flour, germinated soybean and roselle flour), SFRS (Sorghum flour, roasted soybean and roselle flour) SF (Sorghum Flour)

Table 4. Colour parameters of soy-sorghum-roselle complementary food

Samples	L	a*	b*	b/a	Tan^{-1} b/a	∆C	∆E
GSGS	50.60±0.42^{d}	8.58±0.92^{c}	13.12±0.13^{bc}	1.53±0.00^{a}	55.82±0.14^{b}	15.23±0.16^{cd}	38.91±0.33^{a}
GSRS	54.40± 0.28^{c}	9.84±0.92^{b}	11.80±0.57^{d}	1.20±0.00^{e}	50.19±0.13^{d}	14.91±0.10^{d}	35.30±0.21^{b}
FSGS	64.14±3.54^{a}	12.06±0.86^{a}	17.88±1.12^{a}	1.48±0.14^{c}	56.01±0.24^{a}	21.13±1.41^{a}	30.76±1.59^{d}
FSRS	59.44±0.59^{b}	11.23±0.12^{a}	14.18±0.20^{b}	1.26±0.01^{d}	51.50±0.92^{c}	17.58±0.23^{b}	32.19±0.37^{cd}
SFGS	50.45±1.84^{d}	9.50±0.36^{b}	14.11±0.59^{b}	1.50±0.00^{b}	56.19±0.92^{a}	16.62±0.69^{bc}	39.62±1.38^{a}
SFRS	50.26±0.50^{d}	10.27±0.00^{b}	11.38±0.01^{d}	1.11±0.00^{f}	47.94±0.01^{e}	14.87±0.14^{d}	39.08±0.04^{a}
SF	57.40±0.34^{bc}	11.47±0.07^{a}	12.36±0.78^{cd}	1.08±0.00^{g}	47.13±0.01^{f}	16.41±0.11^{bc}	33.16±0.01^{c}

Values are mean±starndard deviation of triplicate scores. Column means with different superscripts are significantly different at 5% probability level (P≤ 0.05). Key: Key: GSGS (Germinated sorghum, germinated soybean and roselle flour), GSRS (Germinated sorghum, roasted soybean and roselle flour), FSGS (Fermented sorghum, germinated soybean and roselle flour), FSRS (Fermented sorghum, roasted soybean and roselle flour), SFGS (Sorghum flour, germinated soybean and roselle flour), SFRS (Sorghum flour, roasted soybean and roselle flour) SF (Sorghum Flour)

Table 5. Sensory evaluation of soy-sorghum-roselle complementary food

Sample	Colour	Aroma	Taste	Mouth feel	Overall acceptability
GSGS	7.07±1.11^{ab}	6.60 ±1.33^{ab}	6.40±1.48^{ab}	6.30±1.24^{a}	6.67±1.45^{a}
GSRS	6.70±1.68^{abc}	6.93±1.26^{a}	6.20±1.54^{ab}	6.37±1.40^{a}	6.60±1.48^{a}
FSGS	7.20±1.32^{ab}	6.43±1.43^{ab}	6.37±1.61^{ab}	6.53±1.43^{a}	6.77±1.70^{a}
FSRS	6.90±1.16^{abc}	6.73±1.23^{a}	6.93±1.68^{a}	6.67±1.71^{a}	7.07±1.70^{a}
SFGS	6.27±1.46^{c}	6.00±1.20^{b}	5.90±1.54^{b}	6.10±1.79^{a}	6.43±1.41^{a}
SFRS	7.43±1.19^{a}	6.50±1.01^{ab}	6.00±2.00^{b}	6.00±1.34^{a}	6.73±1.53^{a}
SF	6.63±1.16^{bc}	6.33±1.12^{ab}	5.53±1.57^{b}	5.83±1.49^{a}	6.53±1.43^{a}

Values are mean±starndard deviation of forty scores. Column means with different superscripts are significantly different at 5% probability level (P≤ 0.05). Key: Key: GSGS (Germinated sorghum, germinated soybean and roselle flour), GSRS (Germinated sorghum, roasted soybean and roselle flour), FSGS (Fermented sorghum, germinated soybean and roselle flour), FSRS (Fermented sorghum, roasted soybean and roselle flour), SFGS (Sorghum flour, germinated soybean and roselle flour), SFRS (Sorghum flour, roasted soybean and roselle flour) SF (Sorghum Flour)

4. CONCLUSION

The results from this study showed that processing methods have marked effect on the proximate, functional, pasting and sensory properties of the complementary foods produced from soybean, sorghum and roselle calyces. Germination resulted in increased protein content in SFGS and GSGS, roasting caused an increase in fat content and improved aroma. All the three processing methods employed (germination, fermentation and roasting) also increased the ash contents of the samples subjected to them. FSRS with least WAC and packed bulk density values would provide a more nutrient-dense food for an infant. Observably from the results, soybean flour substitution reduced significantly (P≤0.05) the packed bulk density (PBD) and swelling capacity (SC) of the complementary foods. Processing resulted in loss of pigments (as evident in loss of colour) in the raw materials as shown in the colour analysis. The complementary foods from fermented sorghum and roasted soybean flour (FSRS) had significantly (p≤0.05) higher mean score in taste, mouthfeel and overall acceptability. It is recommended therefore, that germination, fermentation and roasting methods be employed in preparation of complementary foods.

COMPETING INTERESTS

The authors declare that they have no competing interests.

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