Single Screw Extrusion Processing of Enriched Snacks at Various Levels of Brewers Spent Yeast and Soybean Meal

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ABSTRACT

In the current years, the significance of a healthful diet, dietary composition, and food quality has been gradually heightened because of more and more conscious of the health-promoting constituent of foods by consumers. Thus, the study examined the production of enriched ready-to-eat snacks through extrusion from composite non-wheat based cereal flour of yellow maize. All raw materials were obtained from local markets across Ondo and Osun states markets after which they were sorted, cleaned, dried and milled into a powder. Samples were formulated in the following ratios (yellow maize/ defatted soy flour/ brewers' spent yeasts): 35:30:10 (YMDS), 35:25:15 (YMDD), 35:20:20 (YMDB), 35:10:30 (YMDF) and they were compared with a wheat-based market snack which was the control. The functional, proximate, minerals, antioxidant and sensory properties of the snacks were analysed using standard methods. Results on dry basis established that an increase in brewers' spent yeast substitution in the formulation significantly ($p \leq 0.05$) increased protein (23.07 - 26.84%) and carbohydrate (43.26 – 74.73 %) contents. While crude fibre (5.50-6.69%), ash (8.71-8.86%) and fat contents (13.37-17.85%) significantly increased with defatted soy substitution ($p \leq 0.05$). However, total phenol, ascorbic acid, and total flavonoid contents also increased significantly with defatted soy flour substitution. Finally, no significant difference ($p \leq 0.05$) among all the sample appearance, taste, aroma, and texture (crispness) and sample (YDMF) favourably compared with a market snack in the sensorial properties evaluated and was generally more accepted.

Keywords: *Non-wheat, Composite flour, Defatted, Functional properties, Proximate composition.*

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Highlights of this paper

- This study examined the production of enriched ready-to-eat snacks through extrusion from composite non-wheat based cereal flour of yellow maize.

1. INTRODUCTION

Extruded merchandise like snacks and breakfast cereals are very famous today because of their crunchy texture, which arises from the honeycomb shape imparted to the food material in the course of extrusion [1]. The trend on the consumption of ready-to-eat, handy and less pricey snacks is growing particularly in less evolved countries [2]. But, there is growing consumer interest in ready-to-eat snack foods due to their vast availability, appearance, taste and texture [3]. Expanded ready to eat snacks are produced to meet a number of needs, using a combination of cereals and other ingredients.

Okafor and Ugwu [4] expressed that highly dense protein snacks may be produced via the combination of cereals with different animal sources or, with more cost-effective and available plant sources, consisting of legumes and oilseeds. However, some traditional snacks had been made from such combinations but they are less shelf-stable, especially when stored at room temperature. Interestingly, most industrial production of expanded snacks with the usage of extrusion, drying and baking technologies yielded hygienically processed, acceptable products and shelf-stable [5]. Extrusion cooking has been a modern technology employed in many industries that produce new and unique snacks foods [6]. The cooking process is a high temperature short-time (HTST) process which involves simultaneous thermal and pressure treatment along with mechanical shearing, resulting in changes such as gelatinization of starch, denaturation of protein, and at times entire cooking of the extrudates to obtain ready-to-eat merchandise [7].

Maize or corn (*Zea mays* L.) is considered as an essential annual cereal crop that is eaten as a staple meal in many parts of the world. They are extensively used as major raw materials for the formulation and development of extruded snack foods owing to their good expansion characteristics brought about by their high starch contents [8]. The physical characteristics of snacks, such as expansion, density and hardness, is reported by Launay and Lisch [9] to be a critical parameter that affects the functional characteristics and acceptability of the ultimate products.

Soybean (*Glycine max*) is an affordable and a topnotch source of quality plant protein because it has a good balance of the vital amino acids and it constitutes a reasonable quantity of methionine deficient in sorghum, making it a good supplement for cereals. Fukushima [10] stated that the soybean protein constitutes approximately 40 % of the total solids and plays a very important position within the enrichment of cereal-based foods.

Jarmołowicz, et al. [11] unequivocally verbalized the utilization of single-cell protein of brewer's spent yeast (*Saccharomyces cerevisiae*) is progressively finding a stand in the food industry, because of its high functional properties. However, spent brewer's yeast does not only serve as a good furnish of less expensive protein (45–60%), B-vitamins, minerals, and other substances from the wort, but on the other hand, it can be a super furnish of a number of valuable ingredients with pro-health properties consisting of β-glucans or mono- and oligosaccharides.

Cacao beans (*Theobroma cacao*) had been used globally as a dominant ingredient of cocoa and chocolate. It is rich in polyphenols and contains a high level of flavonoids, specifically epicatechins, which may additionally have beneficial cardiovascular effects on health [12].

The seeds of African locust bean (*Parkia biglobosa*) are extensively used for its dietary values. Nutritionally, locust beans are rich in protein, vitamin B_2, lipids, and lysine when fermented and are mostly used as culinary product to enhance meatiness in soups, sauces and other prepared dishes [13].

Ginger (*Zingiber officinale* roscoe) is an underground stem (rhizome) comprises gingerols and oleoresin (a combination of volatile oils and resin) that accounts for the characteristic aroma and therapeutic properties with numerous health benefits. It reduces the risk of colon most cancers, obesity, bloodless related-sickness and arthritis. It also has anti-inflammatory and anti-oxidative properties for controlling the process of ageing [14].

African walnut (*Tetracarpidium conophorum*) is a less popular nut fruit that is regionally cultivated commonly for the nuts which are cooked and eaten as snacks. It is a good source of essential fatty acids (linoleic acid is its major fatty acid), tocopherols and tocotrienols, proteins, fibers, melatonin, sterols, folate, tannins and other polyphenols [15].

The use of composite flour in the formulation of ready to eat snacks is specifically carried out to satisfy specific functional characteristics and nutrient composition. According to Devi, et al. [16] many extruded products are commonly made from cereals such as wheat, rice and corn. These cereals are rich in carbohydrates and fibers but relatively low in protein content, thus the need to enhance the protein content in the extruded ready to eat products. More so, the increasing demand for healthy extruded snack foods has prompted many industries to intensify focus in research and product development to create products that are nutrient-dense [17]. Therefore, the study examined the formulation, development and assessment of physicochemical and organoleptic properties of enriched ready to eat snacks from composite non-wheat based flour comprising yellow maize flour, defatted soybean flour and brewers' spent yeasts to tackle the menace of protein-malnutrition in the less developed world.

2. MATERIALS AND METHODS

2.1. Materials

The raw materials viz., yellow maize (*Zea mays*), defatted soybean (*Glycine max*) and other ingredients (cocoa powder, ginger, locust beans, walnut, pepper and salt) used for this research were sourced across Oba market in Akure, Ondo State and Ota-Efun market in Osogbo Osun State.While brewers' spent yeast (*Saccharomyces cerevisiae*) was obtained from International Brewery Ilesha, Osun State. A table top single screw food extruder sourced at the Famex Zero Waste Farm Ilesha, Osun State. All reagents used for the analyses were of analytical grade.

2.2. Methods

2.2.1 Production of Maize Flour

The yellow maize flour used was produced following the procedure adopted by Barber, et al. [18] with slight modification. The dry maize grains were sorted to remove extraneous matters before the maize was dry milled into flour using attrition mill and stored in airtight container at a cool environment until when needed for further analysis.

2.2.2. Preparation of Defatted Soy flour

The soybeans grains required for the production were carefully sorted to remove dirt and other extraneous materials such as damaged seeds, stones and sticks. Then, the grains were washed and oven dried after which the soybeans were roasted, decorticated, winnowed and milled into fine flour using hammer mill (Model EU 5000 D). The resultant flour was packed and sealed in polyethene bags until when needed [19].

2.2.3. Formulation of Composite Blends

The yellow maize-soy composite flour were prepared by blending them at varying proportions with other ingredients as shown in the Table 1.

Table-1. The composition of ingredients and formulated proportion.

Ingredients	YMDS (%)	YMDD (%)	YMDB (%)	YMDF (%)
Yellow maize	35	35	35	35
Walnut	5	5	5	5
Ginger	5	5	5	5
Cocoa powder	5	5	5	5
Roasted locust beans	5	5	5	5
Pepper/Salt	5	5	5	5
Autolyzed brewers' spent yeasts	10	15	20	30
Defatted soybean	30	25	20	10

2.2.4. Extrusion Process

Extrusion cooking was carried out using locally fabricated table top single screw food extruder by Famex Zero Waste Farm Ilesha, Osun State. The extruder configuration includes: Length/Diameter ratio of 304:18, screw diameter of 18mm, power of 13HP, barrel length of 304mm and exit die diameter of 3mm. The extruder was used at same speed in all the runs involving same combinations of parameters which include: barrel and die temperature, and the screw speeds. The composite flour was prepared into dough by mixing with appropriate amount of autolyzed brewers' spent yeasts fluid and fed into the locally fabricated table top single screw extruder as shown in Figure 1.

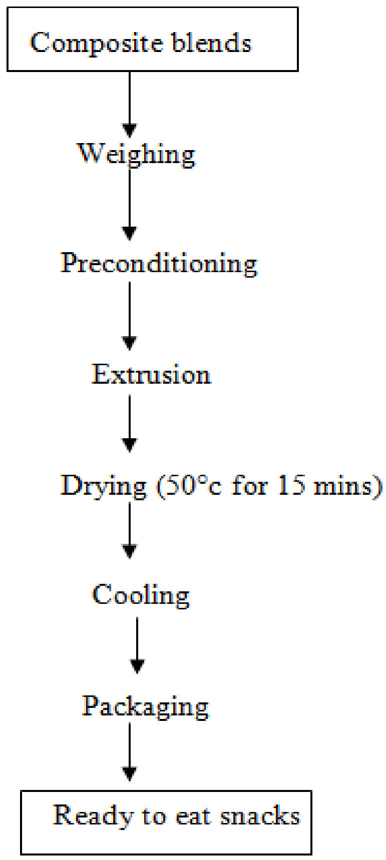

Figure-1. Production of ready-to-eat snacks.

2.3. Analyses Carried Out

On all the formulated samples, the functional properties of composite blends, physicochemical and phytochemical properties, mechanical strength and sensory attributes of the ready-to-eat extruded snacks were carried out.

2.3.1. Chemical Analysis of the Products

Proximate composition (moisture, protein, fibre, ash, fat and carbohydrate) of the extruded ready to eat samples were analyzed using the methods adopted by AOAC [20]. Likewise, the micronutrient content (Na, K, Ca, P, Zn and Fe) of the expanded snacks was determined as explained by James [21].

2.3.2. Phytochemical Determination

The total flavonoid content of the sample was analyzed using a colourimeter assay developed by Bao, et al. [22]. Ascorbic content was determined using the method adopted by Osborne and Voogt [23] and the total phenol was evaluated according to the procedure described by Singleton, et al. [24].

2.3.3. Functional Properties Determination

2.3.3.1. Bulk Density Determination

Bulk density of the composite blend samples was determined using method described by Jones, et al. [25]. 50 g flour sample was put into a 100-mL measuring cylinder. The cylinder was tapped continuously until a constant volume was obtained. The bulk density (g/ml) was calculated as weight of flour (g) divided by flour volume (ml).

2.3.3.2. Water Absorption Capacity

The water absorption capacity of the blends was evaluated with the use of method described by Sosulski, et al. [26]. One gram of the formulated samples was mixed with 10 mL distilled water, stirred using a glass rod and allowed to stand at ambient temperature for few minutes, then centrifuged for 30 min at 2,500 rpm. The supernatant was carefully decanted and then measured. The water absorption capacity was expressed as percentage increase of the sample weight.

2.3.3.3. Swelling Capacity

Swelling capacity was analyzed with the modification of Okaka and Potter [27].100 ml graduated cylinder was filled with 10g of the formulated flours, then 60ml distilled water was added to each cylinder. The top of the graduated cylinder was tightly covered and mixed by inverting the cylinder. The suspension was observed and inverted again after 1 hour and left to stand for a further 3 hours and the volume occupied by the sample was taken after the 4th hours.

2.3.3.4. Least Gelation Capacity

The composite flour dispersions of 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, and 30% (w/v) prepared in 5 ml distilled water was heated at 90°C for 1 h in water bath. The contents were cooled under tap water and kept for 2 h at 10 ± 2°C. The least gelation concentration was determined as that concentration when the sample from inverted tube did not slip [28].

2.3.4. pH Determination

pH of all the sample blends was determined as described by AOAC [20]. A total of 2g of composite blend samples were weighed, diluted in 50ml distilled water at 26 ± 20^{c}, agitated for few minutes. The pH was measured after the solution rested for 5 minutes by dipping the pH meter probe into the solution while the reading was noted.

2.3.5. Mechanical Strength Determination

The mechanical strength was determined by the method described by Inazu, et al. [29]. Known weight was placed on each sample and increased gradually until fracture was experienced.

2.4. Sensory Evaluation of the Ready to Eat Snacks

The sensory evaluation enriched ready to eat snacks was carried out using the method of Larmond [30]. 30 semi-trained panelists were used from the Department of Food Science and Technology, Federal University of Technology, Akure. Panelists were selected on the basis of their willingness and commitment to partake in the sensory assessment, availability and familiarity with snack products. Evaluation was carried out with respect to the snack appearance, texture (crispness), taste, aroma, and the overall acceptability. Panelists evaluated the samples on a 9-point Hedonic scale, ranging from like extremely to dislike extremely.

2.5. Statistical Analysis

All data obtained in the study were subjected to analysis of variance (ANOVA) using SPSS version 22.0 (IBM SPSS, USA), and significant means were separated using the Duncan Multiple range (DMR) test with significance level at $p < 0.05$.

3. RESULTS AND DISCUSSION

3.1. Proximate Composition of the Enriched Ready-To-Eat Snacks

The result of the proximate composition of the enriched snack samples in dry basis is presented in Table 2. The ash content which is the residue left after destroying the samples organic matter, ranged from 8.57-8.85 % while there was no significant difference in the ash content among the samples produced from 10 % and 30 % soybean and spent yeasts substitution, samples produced from 100 % wheat as recorded by Bolarinwa, et al. [31] and 30 % cowpea substitution are significantly different in term of ash content. Thus, due to the high level of ash in the samples, this implied that the samples are rich in mineral elements.

The fat content of the enriched snacks improved with increasing substitution with soy flour. The result obtained for fat determination revealed vast significant differences among the samples at ($p<0.05$). Among the snacks samples, 30 % defatted soy flour had the very best fat content (17.85%) at the same time the lowest value (3.88%) was noted in 100% wheat samples. The fat content of the samples was relatively high because of the residual fat content of the defatted soy flour used for the mixes. The fat content (12.31-17.85%) of defatted soy-corn blends obtained in this study is similar to the fat content of Shakpo and Osundahunsi [32] soy-corn composite flour (11.94-25.04%).

The values obtained from crude fibre determination ranged from 5.50 to 7.58%, the sample with least value was 10% soy and 30% spent yeasts substitution (5.50%) and the highest value was observed in the sample with 25% defatted soy and 15% spent yeasts substitution. Fibre is crucial for the elimination of waste from the body thus, preventing constipation and many health disorders such as obesity and diabetes mellitus [33]. However, the high level of fibre content in the enriched snacks suggests that the snack has a great potential for application as diabetic food.

Table-2. Proximate Composition of the enriched ready-to-eat snacks (Dry Weight Basis).

Samples	Ash (%)	Fats (%)	Fiber (%)	Protein (%)	CHO (%)
YMDS	8.86±0.58^{a}	17.85±0.58^{a}	6.69±0.23^{ab}	23.07±0.26^{c}	43.26±0.60^{b}
YMDD	8.57±0.57^{a}	15.07±0.96^{b}	7.58±0.33^{c}	23.91±0.16^{b}	45.31±1.26^{ab}
YMDB	8.85±1.15^{a}	12.31±0.27^{c}	5.90±0.29^{bc}	25.85±0.15^{a}	47.41±1.07^{b}
YMDF	8.71±0.83^{a}	13.37±0.42^{bc}	5.50±0.31^{c}	26.84±0.25^{a}	46.00±0.44^{ab}
WCDF	1.61±0.05^{b}	3.88±0.01^{b}	4.84±0.01^{d}	14.94±0.01^{d}	74.73±0.10^{c}

Note: Values are mean ± Standard error mean of triplicate determinations. Means with the same superscripts in the column are not significantly different (P>0.05).

KEYS: YMDS = 35% Yellow maize, 30% defatted soy flour, 10% brewers' spent yeasts.
YMDD= 35% Yellow maize, 25% defatted soy flour, 15% brewers' spent yeasts.
YMDB= 35% Yellow maize, 20% defatted soy flour, 20% brewers' spent yeasts.
YMDF= 35% Yellow maize, 10% defatted soy flour, 30% brewers' spent yeasts.
WCDF= Wheat-based snacks. (Control).

The protein content of the enriched snacks improved with brewer's spent yeasts substitution in the mixes. Protein content of the snacks ranged from 23.07% to 26.84%. The protein content of the snacks was higher than the values [31] obtained for 100% wheat flour (14.94%). Among the snack samples, the sample with 10% defatted soy flour and 30% brewer's spent yeasts substitution had the highest protein content (26.84%) while the lowest value (23.07%) was observed in sample with 30% soy flour and 10% spent yeasts. The improvement in the protein content of the enriched snacks could be due to the high protein content of brewers' spent yeasts which may be as the result of yeast interior being separated from the cell wall components. Therefore, a large number of free amino acids (including glutamic acid that impacts the flavour) remains in the solution while all of the non-protein fraction and components of heavier proteins associated with the cell wall that were not autolyzed are eliminated from the solution [34]. The increased protein level (26.84 %) obtained for ready to eat snacks in this study is substantially higher than (12.36 %) ready to eat extrudates made by incorporating egg albumin powder at 20 % level into corn and rice four reported by Kocherla, et al. [35].

Hence, intake of this snack could help to provide an adequate amount of most essential amino acids to the body [36]. High crude protein of the enriched snacks signifies that the composite non-wheat based flour can serve as an affordable source of protein to African populace.

Carbohydrate content of the enriched snacks made from yellow maize-defatted soy flour varied significantly ($p < 0.05$) when compared to 100% wheat-based snacks (74.73 %) and decreased with defatted soy flour substitution in the mixes. Highest carbohydrate content was observed in 100% wheat based ready-to-eat snacks (74.73 %) as reported by Bolarinwa, et al. [31] while 30 % defatted soy flour substitution had the lowest value (43.26%). The values obtained for carbohydrates in this study is analogous to the findings of Okoye, et al. [37] who reported a decrease in carbohydrate content (73.4-34.9%) of wheat-soy bean flour. Additionally, Oluwamukomi, et al. [38] reported carbohydrate content of (69.2-74.5%) for wheat-cassava and soy composite flour. The low carbohydrate content of the yellow maize-defatted soy flour suggests that product from the flour can be suited to patient with diabetics and different associated fitness problems.

3.2. Functional Properties of the Composite Flour

The rationale of determining the functional properties of the composite flour was for identification of using the flour for food application or product development [31]. Table 3 shows the results of functional properties of the yellow maize-defatted soy flour blends. The bulk density of the composite flour varied from (0.81-0.80) g/ml which significantly different from wheat flour (0.60g/ml). This revealed that bulk density depends on the particle size, density of the food and initial moisture content of flours [31]. Addition of defatted soy flour increased the bulk density of the composite samples and had been connected with the expansion ratio in describing the degree of puffing in the extrudates [39]. The high bulk density of flour suggests their suitability for use in food preparations. The high bulk density of flour samples influences the quantity and strength of packaging material, raw materials handling and application in moist processing in food industry energy.

Table-3. Functional properties of the composite flours.

Samples	BD(g/ml)	WAC(g/ml)	LGC(g/ml)	SC(g/ml)	pH
YMDS	0.81±0.01[a]	16.74±10.9[b]	18.0±0.00[a]	0.93±0.43[a]	6.98±0.25[a]
YMDD	0.80±0.01[a]	17.74±0.54[b]	16.7±0.00[ab]	1.02±0.40[a]	6.85±0.80[a]
YMDB	0.8±0.0.01[a]	16.67±11.32[b]	14.0±0.00[b]	1.05±0.06[a]	6.80±0.36[a]
YMDF	0.80±0.00[a]	21.78±0.00[a]	14.0±0.12[b]	0.63±0.72[b]	6.75±0.05[a]
WCDF	0.60±0.00 [b]	17.10±0.00 [b]	27.84±0.00[c]	1.21±0.01[c]	6.33±0.10 [b]

Note: Values are mean ± Standard error mean of triplicate determinations. Means with the same superscripts in the column are not significantly different (P>0.05).

KEYS: YMDS = 35% Yellow maize, 30% defatted soy flour, 10% brewers' spent yeasts.
YMDD= 35% Yellow maize, 25% defatted soy flour, 15% brewers' spent yeasts.
YMDB= 35% Yellow maize, 20% defatted soy flour, 20% brewers' spent yeasts.
YMDF= 35% Yellow maize, 10% defatted soy flour, 30% brewers' spent yeasts.
WCDF= Wheat flour. SC = Swelling Capacity.BD =Bulk Density.
WAC = Water Absorption Capacity, LGC= Least gelation capacity.

The pH value of the yellow maize flour substituted with 30% defatted soy flour and 10% brewers' spent yeasts (6.98) was higher than that of the other samples, while the formulated composite flour pH significantly different to the whole wheat at ($p < 0.05$). This range indicates that the flour can therefore be used to produce suitable products for people suffering from stomach or peptic ulcer [31].

The water absorption capacity (WAC) of the composite blends varied from 16.67 to 21.78% and similar to the values of whole wheat flour (17.10%) reported by Bolarinwa, et al. [31]. It represents the ability of a product to associate with water under limited water conditions [40]. The water absorption capacity is useful in the development of ready to eat foods, which a high WAC may assure product cohesiveness [41] and low WAC product will be easily digestible. High WAC of the composite flours equally suggests that the flours can be used in formulation of some foods such as sausage, dough, processed cheese and bakery products. The increase in the WAC has always been linked with increase in the amylose leaching and solubility, and loss of starch crystalline structure [42]. The values of swelling capacity varied from (0.63-1.05g/ml) which was significantly different from wheat flour (1.21g/ml) at ($p < 0.05$). The swelling capacity of flours depends on size of particles, types of variety and types of processing methods or unit operations.

The least gelation concentration (LGC) obtained for least gelation in this study revealed that LGC of the formulated composite flour increased with increasing soy flour substitution. However, the LGC value obtained for the composite non-wheat flour is relatively low to wheat flour and significantly different at ($p < 0.05$). The lower the LGC, the better the gelating ability of the protein ingredient and the swelling ability of the flour [43].

3.3 Phytochemical composition of the enriched snacks.

The results of antioxidant properties of the enriched ready-to-eat snacks from composite non-wheat flour of yellow maize-defatted soy and autolyzed brewers' spent yeasts is presented in Table 4. The value of total flavonoids content (TFC) for the ready-to-eat snacks ranged from (0.14-0.42) mg/g. It can be deduced that sample YMDS (30% defatted soy-flour and 10% spent yeasts) with the highest value of 0.42 mg/g significantly different from wheat-made snacks. The values reported for the flavonoid content in this study is higher than 0.15% for noodles and 0.09% of steamed bread produced from wheat flour reported by Li, et al. [44]. This increased flavonoid content could be attributed to the high phytochemical properties of cocoa powder and African walnut used as basic and fixed ingredients in the study.

Total phenolic content (TPC) value was between 7.37mg/g in sample YMDF (10% defatted soy flour and 30% brewers spent yeasts) to 14.58mg/g in sample YMDS (30% defatted soy flour and 10% brewers' spent yeasts). The value obtained in this study is significantly higher than 0.33mg/g and 0.22mg/g reported for noodles and steamed bread from wheat flour respectively at ($p < 0.05$).

Table-4. Antioxidant composition of enriched ready-to-eat snacks.

Samples	Flavonoid (mg/g)	Total phenol(mg/g)	Ascorbic acid (mg/g)
YMDS	0.42±0.01^{a}	14.58±0.02^{a}	36.30±0.03 ^{a}
YMDD	0.33±0.00 ^{b}	10.96±0.03^{b}	18.21±0.08 ^{b}
YMDB	0.27±0.00^{c}	8.56±0.01^{c}	11.42±0.07 ^{c}
YMDF	0.14±0.01^{d}	7.37±0.05^{d}	11.32±0.06 ^{c}
WCDF	0.15± 0.02^{e}	0.33±0.96^{e}	15.01±0.35^{d}

Note: Values are mean ± Standard error mean of triplicate determinations. Means with the same superscripts in the column are not significantly different (P>0.05).

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YMDF= 35% Yellow maize, 10% defatted soy flour, 30% brewers' spent yeasts.
WCDF= Wheat-based snacks.

The increase in the TPC can be attributed to the African walnut and locust beans present in the enriched snacks due to the fact that cocoa powder has low phenolic compound. It was also observed that the TPC increased with increase in the percentage of defatted soy four. The polyphenol content of ingredients in enriched snacks development is essential because it gives a direct indication of the health-promoting property of the ready-to-eat snacks.

The ascorbic acid content (AAC) ranged from to (11.32-36.60) mg/g in which sample YMDS had the highest value (36.60) mg/g while sample YMDF had the lowest value (11.32) mg/g. It was observed that the value of ascorbic acid content increased with increasing soy flour substitution which can be due to the reduction of anti-nutritional agents in the defatted soy flour used [45]. Ascorbic acid plays a key nutritional role in foods. It is an essential nutrient for humans, a deficiency of which causes scurvy. It is also a potent antioxidant, protecting the body from oxidative stress. The demand for natural antioxidants has improved because of the long-term safety and negative perception of synthetic antioxidants. In addition to improving food quality and stability, natural antioxidants also act as nutraceuticals to scavenge free radical chain reactions in biological systems and therefore provide additional health benefits to their performance as functional foods [46].

3.3. Mineral Composition of the Enriched Ready-to-Eat Snacks

Mineral compositions of the composite flour are presented Table 5. The potassium, calcium and zinc content of the enriched snacks improved with increasing brewers' spent yeasts substitution and yellow maize flour, while the sodium and iron content reduced as the proportion of soy flour decreases in the composite blend mixes. The results obtained for zinc ranged from (0.53-0.98) mg/100g with the least value obtained for 30% defatted soy flour and 10% spent yeasts (0.53mg/100g) and the highest value recorded for 30% spent yeasts substitution sample (0.98 mg/100g).

The zinc content (0.53-0.98 mg/100 g) of the enriched ready to eat snacks developed in this study is greater than the zinc content (0.053-0.092 mg/100 g) of wheat flour and wheat-soy flour reported by Winiarska-Mieczan and Kwiecień [47]. The results obtained potassium and calcium ranged from (92.67-220.30mg/100g); (3.37-5.83mg/100g) respectively. However, there was significant difference ($p<0.05$) among the samples in term of zinc, potassium and calcium. Also, the results obtained for iron content ranged from (6.10-9.65mg/100g), the least value was recorded for sample from 10% soy flour substitution (6.10mg/100g) and the highest value is obtained from sample with 30% soy flour substitution (9.65mg/100g). The results obtained for sodium likewise varied from (68.28-74.20mg/100g). All the values were significantly different ($P < 0.05$). Although sodium helps in maintaining the water balance in the body, absorption and transmission of some nutrients, and also in transmission of nerve impulses, the health practitioners have encouraged reduction in the intake of sodium because it has been found out to increase the rate of high blood pressure in salt sensitive individuals.

Table-5. Mineral Composition of the enriched ready-to-eat snacks.

Minerals	YMDS(mg/100g)	YMDD(mg/100g)	YMDS(mg/100g)	YMDF(mg/100g)
Zn	0.53±0.01^{b}	0.57±0.01^{c}	0.62±0.01^{b}	0.98±0.01^{a}
Fe	9.65±0.04^{a}	9.50±0.04^{b}	7.42±0.03^{c}	6.10±0.02^{d}
Ca	5.19±0.03^{b}	4.04±0.03^{c}	3.73±0.02	5.83±0.05^{a}
K	109.62±0.07^{b}	97.00±0.00^{c}	92.67±0.09^{d}	220.30±0.15^{a}
Na	74.20±0.15^{b}	68.28±0.45^{c}	71.05±0.83^{a}	68.47±0.35^{c}
P	33.45±0.07^{c}	32.87±0.04^{b}	34.75±0.02^{a}	33.75±0.24^{b}
Na/K	0.67±0.50^{b}	0.70±0.03^{c}	0.77±0.02^{d}	0.31±0.02^{a}
Ca/P	0.16 ±0.20^{b}	0.12±0.02^{c}	0.11±0.00^{d}	0.17±0.00^{a}
Ca/K	0.05±0.03^{ab}	0.04±0.02^{b}	0.04±0.00^{b}	0.03±0.00^{a}

Note: Values are mean ± Standard error mean of triplicate determinations. Means with the same superscripts in the column are not significantly different (P>0.05).
Keys: YMDS = 35% Yellow maize, 30% defatted soy flour, 10% brewers' spent yeasts.
YMDD= 35% Yellow maize, 25% defatted soy flour, 15% brewers' spent yeasts.
YMDB= 35% Yellow maize, 20% defatted soy flour, 20% brewers' spent yeasts.
YMDF= 35% Yellow maize, 10% defatted soy flour, 30% brewers' spent yeasts.
WCDF= Wheat-based snacks.

The Na/K and Ca/P ratios are indices of body electrolyte balance and bone formation and the values were relatively high in this study. For instance, Na/K molar ratio range from 0.31 for YDMF to 0.77 for YMDS, while that of Ca/P molar ratio was between 0.11 for YDMB (20% soy flour and 20% brewers' spent yeasts) and 0.17 for YDMF ((10% soy flour and 30% brewers' spent yeasts) sample. The Na/K ratio less than 1 is recommended for diets, especially for hypertensive patients. Therefore, the observed Na/K molar ratio of the enriched ready-to-eat snacks in this study is suitable for people who have the risk of high blood pressure [48].

3.4. Mechanical Strength of the Ready-To-Eat Snacks

Mechanical strength of food materials indicates the amount of weight the substance can withstand without fracture or crack especially during bulk packaging in the warehouse and distribution to the consumers. It is useful in the packaging of ready-to-eat foods and transportation of the products across the distribution stores [29]. It was observed that the level of mechanical strength of the samples increased with increasing defatted soy flour substitution as shown in Table 6. Mechanical strength of the ready-to-eat snacks ranged from (186-295g). At 82.50g, only sample WCDF (wheat-snacks) was unable to withstand the weight while the other formulated samples favourably withstood the weight which could be as the result of the defatted soy flour substitution. However, sample YMDS had the highest cracking strength which was at 295g. This implies the sample will able to withstand transport stress. While sample YMDF had the lowest cracking weight (186g) which may be attributed to low percentage of defatted soy flour in the sample.

Table-6. Mechanical strength of ready-to-eat snacks.

Samples	Cracking weights (g)
YMDS	295.35
YMDD	268.65
YMDB	222.65
YMDF	186.65
WCDF	82.50

Note: KEYS: YMDS = 35% Yellow maize, 30% defatted soy flour, 10% brewers' spent yeasts.
YMDD= 35% Yellow maize, 25% defatted soy flour, 15% brewers' spent yeasts.
YMDB= 35% Yellow maize, 20% defatted soy flour, 20% brewers' spent yeasts.
YMDF= 35% Yellow maize, 10% defatted soy flour, 30% brewers' spent yeasts.
WCDF= Wheat-based snacks.

3.5. Sensory Evaluation of the Enriched Ready-to-Eat Snacks

The sensory scores from the sensory evaluation of the enriched ready to eat snack samples as shown in Table 7, no significant difference in all the parameters assessed and the values varied between 6.17 and 6.80 for sensory properties tested including aroma, appearance, texture (crispness), tastes and overall acceptability. However, the developed ready-to-eat snack samples were significantly different ($p<0.05$) from the 100% wheat-made snacks in terms of aroma, appearance texture and taste. In terms of general acceptability, samples with 10% defatted soy flour and 30% brewers' spent yeasts were mostly acceptable to the panelists. Thus, the composite flour obtained from yellow maize with 10% defatted soy blend and 30% brewers' spent yeasts substitution could be used to produce acceptable ready to eat product.

Table-7. Sensory evaluation of the enriched ready-to-eat snacks.

Samples	Aroma	Appearance	Crispness	Taste	Acceptability
YMDS	6.27 ± 0.24^a	6.23 ± 0.18^a	6.73 ± 0.21^a	6.53 ± 0.26^a	6.50 ± 0.24^a
YMDD	6.27 ± 0.20^a	6.37 ± 0.18^a	6.56 ± 0.23^a	6.00 ± 0.26^a	6.60 ± 0.16^a
YMDB	6.27 ± 0.24^a	6.47 ± 0.25^a	6.30 ± 0.20^a	6.17 ± 0.27^a	6.37 ± 0.23^a
YMDF	6.40 ± 0.21^a	6.60 ± 0.16^a	6.67 ± 0.25^a	6.50 ± 0.20^a	6.80 ± 0.22^a
WCDF	6.78 ± 0.76^b	7.75 ± 1.10^b	6.89 ± 0.30^a	7.72 ± 0.83^b	7.78 ± 0.94^b

Note: Values are mean ± Standard error mean of triplicate determinations. Means with the same superscripts in the column are not significantly different ($P>0.05$).
KEYS: YMDS = 35% Yellow maize, 30% defatted soy flour, 10% brewers' spent yeasts.
YMDD= 35% Yellow maize, 25% defatted soy flour, 15% brewers' spent yeasts.
YMDB= 35% Yellow maize, 20% defatted soy flour, 20% brewers' spent yeasts.
YMDF= 35% Yellow maize, 10% defatted soy flour, 30% brewers' spent yeasts.
WCDF= Wheat-based snacks.

4. CONCLUSION

This study has demonstrated that increasing the percentage of non-wheat composite flour with defatted soybeans blends and brewer's spent yeasts for development of expanded ready to eat snacks production enhanced the protein, mineral, mechanical strength and antioxidant properties of the snacks. Additionally, substitution of non-wheat based composite flour with 30% autolyzed brewers' spent yeasts resulted in a notable improvement in protein content while 30% defatted soy flour resulted in increased phytochemical properties. The samples with 10% defatted soy flour and 30% brewers' spent yeasts were most acceptable to panelist. Then, increasing the lowest defatted soy flour and brewers' spent yeasts substitution level in the formulation from 10% to 30% could result in products with improved nutritional values and eating quality. Therefore, the composite flour products could be nutritionally superb to Africa, the place where many people can barely afford animal proteins.

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