International Journal of Food Science and Nutrition Engineering 2020, 10(1): 1-11
DOI: 10.5923/j.food.20201001.01

Anti-nutrients, Bioaccessibility and Mineral Balance of Cookies Produced from Processed Sesame Seed Flour Blends

Akusu O. M.*, Kiin-Kabari D. B., Isah E. M.

Department of Food Science and Technology, Rivers State University, Port Harcourt, Nigeria

Abstract Sesame seed was processed into flour using five different processing methods such as defatting, cooking, roasting, germination and fermentation. The processed sesame seed flour was substituted to wheat flour at 4 levels (5, 10, 15 and 20%) with other ingredients to produce cookies. Effect of processing methods on anti-nutritional content of the flour blends, total mineral contents, in-vitro mineral bioaccessibility and mineral balance of the produced cookies were determined. Result revealed that raw sesame seeds had anti-nutrient values of 1.21mg/100g, 87.47mg/100g and 29.45mg/100g for phytate, oxalate and total phenol, respectively while processing methods revealed a significant reduction ($P<0.05$) in the values of these anti-nutrients that were analysed. In terms of the total mineral, calcium, magnesium and iron content of the cookies ranged from 2220.95 – 2916.9mg/100g, 257.219 – 278.587mg/100g and 30.573 – 45.550mg/100g, respectively. Percentage mineral bioaccessibility ranged from 40.60 – 97.856%, 15.077 – 92.144%, 25.054 – 97.677%, 2.542 – 89.815% and 25.13 – 98.817% for Zn, Cu, Ca, Mg and Fe, respectively. Bioaccessibility of minerals in the cookies samples increased significantly ($P<0.05$) with increased percentage substitution of cooked, roasted and fermented sesame seed flour samples. Cookies with 5% fermented sesame seed flour recorded high percentage bioaccessible zinc and magnesium of 97.856% and 97.907%, respectively. Mineral balance of the cookie samples ranged from 2.144 – 59.399%, 7.856 – 86.336%, 2.32 – 74.946%, 39.955 – 97.548 and 3.759 – 74.87% for Zn, Cu, Ca, Mg and Fe, respectively.

Keywords Processing, Bioaccessibility, Mineral balance, Sesame seed, Cookies

1. Introduction

Cookies are nutritive snacks obtained from single or composite dough which has been transformed into digestible and more appetizing product through the action of heat in the oven [1]. Cookies are classified based on the ingredient composition and processing techniques [2]. Due to increased demand for functional products, attempts are being made to improve the nutritive value and functionality of cookies by modifying their nutritive composition. This involves the use of non-wheat flour with attempt to increase the protein content and quality of the cookies and overcome the problems of high cost of wheat flour due to its importation to Nigeria and other countries whose climates are unfavourable for wheat cultivation. These limitations have prompted the search for available or underutilized crops, seeds and fruits with functional attributes to be incorporated as composite flours, fortifications and enrichments for the production of baked products [3]. As such, cookies as an easy to eat cherished snack has been produced from wheat/cashew apple residue as a source of fibre [4] and *moringa* leaf four has been used as protein fortification and enrichment in cookies production [5,6]. Few has been recorded on the usage of sesame seeds in the production of cookies despite its availability [7] and health benefits that has been reported by many researchers [8-10].

Sesame seeds (*Sesamum indicum*) are tiny, flat oval seeds with a nutty taste. It is an important oil seed believed to have originated from tropical Africa with the greatest diversity [11]. Sesame seed is a staple food among many ethnic groups in Nigeria and it is cultivated in most areas of the middle belt and some northern states of Nigeria [7]. Sesame is an important source of oil (44-52.5%), protein (18-23.5%) and 13% of carbohydrate [9,10]. The seeds are consumed fresh, dried or blended with sugar. It is also used as a paste in some local soups. The meal is notable for its high protein concentration which is rich in methionine and tryptophan. Since these amino acids are missing from a number of other sources of vegetable proteins such as soybean. Thus, sesame seed flour can be added to recipes to give a better nutritional balance to healthy food products [12]. Apart from the

* Corresponding author:
akusu.monday@yahoo.com (Akusu O. M.)
Published online at http://journal.sapub.org/food

mentioned amino acids, sesame seed is also rich in fat, carbohydrates, fibre and some minerals. The oil seed is renowned for its stability because it strongly resists oxidative rancidity even after long exposure to air [13]. The nutritional value of foods depends on their nutrient content and the bioavailability of these nutrients. Enhancement of the nutritional quality of sesame seeds can be anticipated through processing prior to consumption. Sesame is commercialized in a number of forms. Most sesame is processed directly into oil by the grower or within the producing region. It can also be sold in various processing stages for different uses such as meal, paste, confections and bakery products. Furthermore, sesame seeds can be consumed directly as a highly nutritious foodstuff [8]. However, lack of knowledge of the nutritional qualities of lesser known oil seed grown in developing countries like Nigeria is responsible for the poor utilization of these crops in different food formulations. Various processing technologies have helped in transforming food ingredients into healthier products with maximum nutritional value to ensure nutrient security of the population in developing countries [14]. Such techniques include cooking, roasting, defatting, fermentation and germination. These techniques play an important role in ensuring the food security of millions of people around the world, particularly the marginalised and vulnerable groups. This is achieved through improved food preservation, increasing the range of raw materials that can be used to produce edible food products and removing anti-nutritional factors to make food safe to eat [15]. Previous research work on oil based seeds highlight cooking, roasting, germination and fermentation of seeds as being more responsible for providing nutritionally better products than the raw seeds and the enzymes, especially α- amylase aid hydrolysis of the seed macromolecules [16,17] after the application of all these processing methods.

Germination is a complex metabolic process during which the lipids, carbohydrates and stored proteins within the seeds are broken down in order to provide energy and amino acids necessary for the plant development [18]. Likewise, the metabolic changes that take place during different stages of roasting, fermentation and germination influence the bioaccessibility of essential nutrients [19]. Bioaccessibility of a nutrient is the fraction of ingested nutrient that is available for utilization in normal physical functions and storage [20]. Factors that influences its availability include chemical state of the nutrient, its release from food matrix, its interaction with other food components, presence of suppressor and other cofactors, formation of stable components that are easily metabolized [20]. Bioaccessibility of minerals in oil seed products is a less research area but the information is of high significant as oil seeds form major protein sources and is extensively used in complementary and supplementary foods, as well as in bakery products. Although exist numerous studies about the nutritional characteristics of sesame seeds, there is paucity of information on mineral bioaccesebility and mineral balance in value added products such as cookies formulated with roasted, cooked, defatted, fermented and germinated sesame seed flour. Mineral bioavailability can be affected by the presence of the anti-nutritional factors such as phaytate, tannins and polyphenols in foods [21]. The two most important techniques used to improve mineral bioavailability are reducing the phytate content in the foods or adding extra minerals in the fortification and blending process [22,23]. However, their nutritional quality is limited by the presence of anti-nutritional factors that exhibit undesirable physiological effects [24,25]. The anti-nutritional factors, being structurally different compounds are broadly divided into two categories: proteins (such as lectins and protease inhibitors) and others such as phytates, tannins, oligosaccharides, saponins, oxalates and alkaloids [26]. Phytate and oxalate usually found in the seed hulls lower the bioavailability of minerals and digestibility of plant proteins thereby limiting its use as food ingredient [27]. Anti-nutritional factors may also be classified according to their ability to withstand thermal processing, the most commonly employed treatment for destroying them. Heat labile factors include some components like protease inhibitors and lectins, whereas heat stable factors are represented by saponins, non-starch polysaccharides, antigenic proteins, estrogens and some phenolic compounds [28]. The negative impacts of the ingestion of anti-nutritional factors have extensively been reported. For instance, some factors, like trypsin inhibitor, affect protein utilization and digestion while others like phytic acid and tannins, affect mineral utilization [29,28]. Some anti-nutritional factors may exert beneficial health effects at low concentrations. Thus, the manipulation of processing conditions and removal or reduction of certain unwanted components of food may be required, to enhance nutritional quality [30,31]. The most common processing methods required to achieve this includes, cooking, roasting, germination and fermentation. Phytic acid, an anti-nutritional factor from raw sesame seed meal, could be reduced below detection limit by fermentation with lactic acid bacteria (*Lactobacillus acidophilus*) according to Mukhopadhyay [32].

Fermentation technologies play an important role in ensuring the food security of millions of people around the world, particularly the marginalised and vulnerable groups. This is achieved through improved food preservation, increasing the range of raw materials that can be used to produce edible food products and removing anti-nutritional factors to make food safe to eat [15]. Other processing methods, such as soaking, germination and cooking have been reported to improve the nutritional and functional properties of plant seeds [33,34]. This processing techniques can also reduce malnutrition by making micronutrients available for easy absorption; hence, increasing the utilization of sesame seeds. Industrial processing and utilization of sesame have not been fully developed in Nigeria as its utilization is restricted to producing regions. For most part, the surplus crop is commercialized, bulked and exported with minimal processing limited to cleaning and drying. Therefore, the objective of this study was to produce cookies from blends of roasted, cooked, defatted, fermented and germinated sesame seed flour in composite with wheat and to access the mineral bioavailability and mineral balance of the products, as well as the anti-nutrient properties of the processed flour, in view of increased utilization.

2. Materials and Methods

Sesame seeds where purchased from an open market in Anyigba, kogi State. Wheat flour, sugar, margarine, salt, sodium bicarbonate, milk and vanilla flavour were purchased from confectionery store in Port Harcourt, Rivers State and transported in air tight high density polyethylene bag to the Food Chemistry Laboratory in the Department of Food Science and Technology, Rivers State University, Port Harcourt, Nigeria for processing and analysis. Digestive enzymes and bile salt were purchased from Sigma-Aldreich (Merck, Germany). All reagents and apparatus used in this study were obtained from the same Department and were of analytical grade.

2.1. Roasting

The whole seeds of sesame seeds were roasted in an oven at 120℃ for 1hr according to the method described by Mohamed *et al.* [35]. The samples were milled in a Braun (KMM 30, Bico, Chicago) mill to pass through a 0.5mm size sieve and stored in a sealed high density polyethylene bags until required for analysis.

2.2. Cooking

Cooking was done using the method described by Makinde and Akinoso [31]. The whole sesame seeds were cooked at 100℃ for 30min in the seed to water ratio of 1:10 (w/v). Consequently, the seeds were dried by hot air oven (model QUB 305010G, Gallenkamp, UK) at 40℃ prior to milling and storage.

2.3. Defatting

Sesame seeds were sorted, cleaned and milled into flour using Kenwood blender (Model A907D U.K). The flour was oven dried at 105℃ for 1h to reduce the moisture content and to condition the fat molecules of the flour. The oil was extracted by solvent extraction with petroleum ether (b.p 40 – 60℃) in continuous soxhlet extraction apparatus for 3h to obtain defatted sesame seed flour. It was then sieved, packaged and set outside for analysis [36].

2.4. Fermentation

The sesame seeds were dehulled, boiled in water for 6hr and cooled. The cooked seeds were placed in a plastic container with a tight lid and sealed. The samples were allowed to ferment at 35±2℃ for 7 days and oven (model QUB 305010G, Gallenkamp, UK) dried at 105℃ for 12hr to bring an end to fermentation, milled (Sieved with No 30 mesh) to obtain fermented sesame flour and stored in a glass container according to the method described by Akindahunsi [37].

2.5. Germination

Sesame seeds were germinated as described by Okoli and Adeyemi [38]. The seeds were sorted to remove stones and other extraneous materials. It was thereafter soaked for 2hr to achieve hydration then rinsed, drained and spread thinly on jute sack for germination to take place. The germination process was closely monitored to prevent discontinuity of germination and mould growth which was achieved by constant wetting and intermittent uniform spreading of the germinating seedlings. Germination was carried out for three days. The germinated seedlings were thoroughly rinsed with water, drained, derooted, dried in a hot air oven (model QUB 305010G, Gallenkamp, UK) at 60℃ for 6hr and then milled using a laboratory blender (KMM 30, Bico, Chicago) to pass through 0.5mm size sieve and stored in plastic bags until required for analysis.

2.6. Anti-nutritional Composition

2.6.1. Pythate Content

The phytate content was determined using Hassan [39] standard method. Two grams of each finely ground sample was weighed into a 250ml conical flask and 100ml of 2% concentrated HCl was added. Allowed to stand for 3hr and filtered. After filtration, 50ml of the filtrate was pipetted into a 250ml beaker and 107ml of distilled water was added to improve acidity. Ten millimeter of 0.3% ammonium thiocynate solution was added as an indicator. The solution was titrated with standard iron III chloride ($FeCl_3$) which contain 0.00195g iron/ml until a brownish yellow colour appeared and persisted for 5min. The phytic acid content was calculated using the formula below:

$$Phytic\ acid\ g/Kg = \frac{0.00195\ \times Volume\ of\ FeCl3\ consumed\ \times Df}{Sample\ \ weight} \times 1000$$

2.6.2. Total Phenol Content

Total phenolic content (TPC) was determined colorimetrically using Folin-Ciocalteau reagent, as described by Singleton *et al*. [40]. Sample (0.4g) was extracted with 20ml of acidified methanol (1% HCl in methanol) for 1hr at 25℃, with vortex mixing at 5min intervals. Samples were centrifuged for 10min at 1200 rpm. Two replicate sample extract supernatants (0.5ml) was mixed with 2.5ml of Folin-Cicalteau reagent and allowed to stand at 25℃ for 8min. Then 7.5ml of 20% sodium bicarbonate solution was added to the mixture. After 2hr at 25℃, absorbance was measured at 765 nm using a UV-visible spectrophotometer. A standard curve was prepared using various concentration of tannic acid and the results were reported as mg tannic acid equivalents/g of sample.

2.6.3. Oxalate Content

Oxalate was determined following the AOAC [41] standard method. One gram of sample was weighed into 100ml conical flask. 75ml of 3M H_2SO_4 was added and the solution was carefully stirred intermittently with a magnetic stirrer for about 1hr and then filtered using Whatman No.1 filter paper. The sample filtrate (25ml extract) was collected and titrated against hot (80℃ - 90℃) 0.1N $KMnO_4$ solution to the point when a faint pink colour appeared that persisted for at least 30sec. The concentration of oxalate in each sample was obtained from the calculation: 1ml (0.1N) permanganate = 0.006303g oxalate.

2.7. Production of Cookies from Treated Sesame Seed Flours and Wheat Flour

Table 1A. Formulation of Cookie Recipe from the Blends of Wheat/Processed Sesame Seed Flours

SAMPLES	WDSC1	WDSC2	WDSC3	WDSC4	WCSC1	WCSC2	WCSC3	WCSC4	WRSC1	WRSC2	WRSC3	WRSC4
WF	95	90	85	80	95	90	85	80	95	90	85	80
DSSF	5	10	15	20	0	0	0	0	0	0	0	0
CSSF	0	0	0	0	5	10	15	20	0	0	0	0
RSSF	0	0	0	0	0	0	0	0	5	10	15	20
GSSF	0	0	0	0	0	0	0	0	0	0	0	0
FSSF	0	0	0	0	0	0	0	0	0	0	0	0
Sugar	10	10	10	10	10	10	10	10	10	10	10	10
Margarine	30	30	30	30	30	30	30	30	30	30	30	30
Water	50	50	50	50	50	50	50	50	50	50	50	50
Milk	10	10	10	10	10	10	10	10	10	10	10	10
$NaHCO_3$	1	1	1	1	1	1	1	1	1	1	1	1
Salt	2	2	2	2	2	2	2	2	2	2	2	2
Flavour	2	2	2	2	2	2	2	2	2	2	2	2

Table 1B. Production Blends for Wheat/Processed Sesame Seed Flour Cookies

SAMPLES	WGSC1	WGSC2	WGSC3	WGSC4	WFSC1	WFSC2	WFSC3	WFSC4	WFC
WF	95	90	85	80	95	90	85	80	100
DSSF	0	0	0	0	0	0	0	0	0
CSSF	0	0	0	0	0	0	0	0	0
RSSF	0	0	0	0	0	0	0	0	0
GSSF	5	10	15	20	0	0	0	0	0
FSSF	0	0	0	0	5	10	15	20	0
Sugar	10	10	10	10	10	10	10	10	10
Margarine	30	30	30	30	30	30	30	30	30
Water	50	50	50	50	50	50	50	50	50
Milk	10	10	10	10	10	10	10	10	10
$NaHCO_3$	1	1	1	1	1	1	1	1	1
Salt	2	2	2	2	2	2	2	2	2
Flavour	2	2	2	2	2	2	2	2	2

KEY:
WF = wheat flour, DSSF = defatted sesame seed flour, CSSF = Cooked sesame seed flour, RSSF = Roasted sesame seed flour, GSSF = germinated sesame seed flour, FSSF = fermented sesame seed flour.
WDSC1 = WF/DSSF cookies (95/5%), WDSC2 = WF/DSSF cookies (90/10%), WDSC3 = WF/DSSF cookies (85/15%), WDSC4 = WF/DSSF cookies (80/20%).
WCSC1 = WF/BSSF cookies (95/5%), WCSC2 = WF/BSSF cookies (90/10%), WCSC3 = WF/BSSF cookies (85/15%), WCSC4 = WF/BSSF cookies (80/20%).
WRSC1 = WF/RSSF cookies (95/5%), WRSC2 = WF/RSSF cookies (90/10%), WRSC3 = WF/RSSF cookies (85/15%), WRSC4 = WF/RSSF cookies (80/20%).
WGSC1 = WF/GSSF cookies (95/5%), WGSC2 = WF/GSSF cookies (90/10%), WGSC3 = WF/GSSF cookies (85/15%), WGSC4 = WF/GSSF cookies (80/20%).
WFSC1 = WF/FSSF cookies (95/5%), WFSC2 = WF/FSSF cookies (90/10%), WFSC3 = WF/FSSF cookies (85/15%), WFSC4 = WF/FSSF cookies (80/20%).
WFC = Control (100% wheat flour cookies).

Cookies were produced as described by Aliyu and Sani [42] using the formulated of cookie recipe from the blends of wheat and processed sesame seed flours as presented in Table 1A and B. All the weighed ingredients except flours were mixed thoroughly in a Kenwood mixer (a 3-speed hand mixer) and transferred to a bowl. The individual flour samples and sodium bicarbonate were added with continuous mixing for 15min until smooth dough was obtained. A piece of this dough was cut, placed on a clean platform then rolled out using rolling pin until the desired uniform texture and thickness was obtained. Cookie cutter was used to cut the sheet of the dough into required shapes and sizes. These were transferred into a margarine greased baking tray. The baking was done at 200°C and baked for 15 - 20min. After baking, the hot cookies were removed from the pan and placed on a clean tray to cool down. The cookies were then packed after cooling in polyethylene sachets of appropriate thickness and permeability using an impulse sealing machine prior to further analysis and sensory evaluation using 100% wheat cookies as the control sample.

2.8. In vitro Mineral Bioaccessibility

In vitro mineral bioaccessibility was determined with stimulated peptic digestion, titratable acidity and pancreatic digestion method as described by Luten *et al.* [43]. A pepsin solution was prepared by dissolving 16g of pepsin (1:2,500) Cat No P7125 from porcine stomach mucosa) in 100ml of 0.1M HCl. The pancreatic solution contained 4g of pancreatin Cat No P1750 enzymes from porcine pancreas and 25g of bile extract B-8631, porcine in 1000ml of 0.1M $NaHCO_3$.

2.8.1. Peptic Digestion

The sample (10g) was mixed with 80ml of water in a 250ml conical flask. The pH was adjusted to 2.0 by adding 6M HCl and then 3ml of freshly prepared pepsin solution was added and the sample was made up to 100ml with distilled water. After mixing, the sample was incubated at 37°C in a shaking water bath for 2hr.

2.8.2. Titratable Acidity

A homogenous aliquot of pepsin digest (20ml) was taken and 5ml of pancreatic mixture was added. The pH was adjusted to 7.5 with 0.5M NaOH. Titratable acidity was defined as the amount of 0.5M NaOH required in order to reach a pH of 7.5.

2.8.3. Pancreatic Digestion

A homogenous pepsin digest aliquots (20ml) was weighed into a 250ml conical flask. Segments of dialysis tube containing 25ml of water and $NaHCO_3$ were then added immediately to the amount of $NaHCO_3$, being equivalent in moles to the NaOH used to determine the titratable acidity. After 30min, the pH attaining was 7.0 - 7.5, 5ml of the pancreatic mixture was added and the digest were incubated in a shaking water bath for 2hr at 37°C. The dialyzable fraction of mineral which represents the bioaccessible was quantitated by Atomic Absorption Spectrophotometry (atomic absorption spectrophotometer, Shimadzu AA6800, Tokyo, Japan).

Bioaccessibilty (%) was calculated as follows:

$$Bioaccessibility\ (\%) = \frac{Y}{Z} \times 100$$

Where;

Y = element content of bioaccessible fraction (mg mineral element /100g sample), which is the soluble mineral content.

Z = total mineral content (mg mineral element /100g sample)

Mineral balance = 100 – Bioaccessible mineral (%)

2.9. Statistical Analysis

All the analyses were carried out in duplicate samples. Data obtained were subjected to Analysis of Variance (ANOVA). Differences between means were evaluated using Tukey's multiple comparison test, and significance accepted at P≤ 0.05 level. The statistical package in Minitab 16 computer program was used.

3. Results and Discussion

3.1. Anti-Nutritional Composition of Raw and Processed Sesame Seed Flour

Table 2. Anti-Nutritional Composition of Raw and Processed Sesame Seed Flour (mg/100g)

Treatment	Phytate	Total Phenol	Oxalate
Defatted	0.88±0.01^{d}	29.53±0.07^{a}	65.49±0.08^{b}
Cooked	0.63±0.01^{f}	18.72±0.03^{c}	59.88±0.89^{c}
Roasted	0.75±0.01^{e}	15.16±0,01^{e}	50.71±0.40^{d}
Germinated	0.94±0.01^{c}	23.13±0.03^{b}	1.54±0.42^{f}
Fermented	1.00±0.04^{a}	18.03±0.04^{d}	24.74±0.23^{e}
Raw	1.21±0.01^{b}	29.45±0.04^{a}	87.47±0.66^{a}

Values are Mean ± Standard Deviation of triplicate Samples. Values bearing different letters in the same column are significantly different (p<0.05).

Data on phytate, total phenol and oxalate contents of raw and processed sesame seed flours are summarized in Table 2. The result showed that the level of phytate, oxalate and total phenol in raw sesame seeds were 1.21mg/100g, 87.47mg/100g and 29.45mg/100g, respectively. A significant reduction (P<0.05) was observed after cooking, roasting, germination and fermentation. Phytate and total phenol content reduced significantly (P<0.05) after roasting to 0.75 and 15.16mg/100g, respectively. While the oxalate content reduced significantly (P<0.05) after germination to 1.54mg/100g. There was no significant difference (P>0.05) in the total phenol content of the raw and the defatted samples. The phytate and oxalate concentrations of fermented sesame samples were lower when compared with raw sample. This is due to the fact that initial soaking, hydration and cooking of the dehulled seeds had caused leaching of some of these anti-nutrients into the processing water before the actual fermentation process. This is also attributed to diminishing effect of enzymes (phytase and polyphenol oxidase) produced by microorganisms during fermentation on these anti-nutrients. The only factor that could account for the lower concentrations of phytate and oxalate in roasted sesame was the heat applied as these anti-nutrients are thermo labile in nature. Significant reduction of phytate contents by thermal processing (roasting and cooking) has been observed in other plant foodstuff [44-47]. The apparent decrease in phytate content during thermal processing may be partly due; either to the formation of insoluble complexes between phytate and other components, such as phytateprotein and phytate-protein-mineral complexes or to the inositol hexaphosphate hydrolyzed to penta- and tetraphosphate [48]. Makinde and Akinoso [31] also reported significant reduction in phytate and oxalate content of sesame seed four during germination, roasting and cooking.

3.2. Total Mineral Content of Cookies Produced from Wheat/Processed Sesame Seed Flour Blends

Table 3. Total Mineral Content (g/100g) of Cookies Produced from Wheat/Processed Sesame Seed Flour Blends

Cookies	Zinc	Copper	Calcium	Magnesium	Iron
WRSC1	33.294^{a}	13.362^{f}	3674.510^{d}	162.786^{l}	135.366^{a}
WRSC2	19.166^{g}	13.927^{ef}	3513.430^{e}	164.935^{k}	130.188^{b}
WRSC3	17.850^{j}	7.129^{m}	1822.650^{f}	177.713^{f}	120.845^{d}
WRSC4	22.271^{f}	11.891^{g}	1763.590^{g}	170.634^{i}	121.368^{c}
WDSC1	14.419^{m}	9.182^{j}	1247.720^{q}	172.528^{h}	18.454^{o}
WDSC2	13.917^{o}	9.382^{ij}	1345.770^{mn}	177.373^{g}	19.178^{n}
WDSC3	26.566^{d}	9.589^{i}	3869.720^{a}	177.259^{g}	36.318^{g}
WDSC4	31.155^{b}	28.016^{a}	3779.250^{b}	182.719^{d}	46.306^{f}
WCSC1	29.732^{c}	8.873^{k}	3696.450^{c}	172.227^{h}	77.632^{e}
WCSC2	24.373^{e}	8.004^{l}	1293.630^{p}	170.193^{j}	20.138^{m}
WCSC3	17.227^{i}	10.687^{h}	1705.750^{h}	197.958^{a}	29.227^{h}
WCSC4	15.572^{kl}	6.719^{m}	1691.530^{i}	196.701^{b}	18.740^{o}
WFSC1	15.457^{l}	10.809^{h}	1147.890^{r}	162.991^{l}	26.591^{i}
WFSC2	22.473^{f}	9.569^{i}	1397.480^{l}	170.756^{i}	17.504^{p}
WFSC3	18.635^{h}	8.522^{k}	1705.780^{h}	172.538^{h}	22.979^{l}
WFSC4	15.703^{k}	9.808^{i}	1544.370^{j}	170.838^{i}	23.658^{k}
WGSC1	14.516^{m}	18.242^{d}	1326.840^{n}	181.700^{e}	15.446^{r}
WGSC2	15.034^{l}	13.326^{f}	1418.510^{k}	172.8728^{h}	18.787^{o}
WGSC3	14.074^{n}	22.690^{c}	1368.550^{m}	172.251^{h}	16.246^{q}
WGSC4	24.482^{e}	27.518^{b}	1314.500^{o}	189.747^{c}	24.527^{j}
WFC	1.062^{p}	14.150^{e}	3.024^{s}	1.023^{m}	17.020^{p}

Values bearing different superscript in the same column differ significantly (P<0.05).
Key:
WRSC = Wheat:Roasted Sesame Cookies
Samples WRSC1, 2, 3 and 4 (95:5, 90:10, 85:15 and 80:20), respectively.
WDSC = Wheat:Defatted Sesame Cookies
Samples WDSC1, 2, 3 and 4 (95:5, 90:10, 85:15 and 80:20), respectively.
WCSC = Wheat:Cooked Sesame Cookies
Samples WCSC1, 2, 3 and 4 (95:5, 90:10, 85:15 and 80:20), respectively.
WFSC = Wheat:Fermented Sesame Cookies
Samples WFSC1, 2, 3 and 4 (95:5, 90:10, 85:15 and 80:20), respectively.
WGSC = Wheat:Germinated Sesame Cookies
Samples WGSC1, 2, 3 and 4 (95:5, 90:10, 85:15 and 80:20), respectively.
WFC = Wheat Flour Cookies 100%

Total mineral content of cookies produced from wheat flour in composite with roasted, defatted, boiled, fermented and germinated sesame seed flour are presented in Table 3. Result revealed that zinc content of the produced cookies ranged from 1.062 – 33.274mg/100g. An increase in the zinc content of cookies substituted with 5 – 20% defatted sesame seed flour was observed from 14.419 – 31.155mg/100g. While a decreased from 29.732– 15.572mg/100 and 33.294 – 22.272mg/100g was recorded for cookie samples substituted with 5 – 20% cooked and 5 – 20% roasted sesame seed flours, respectively. Increase substitution of fermented and germinated sesame seed flour is shown to increase the zinc content of its cookies. Zinc content of all the composite cookies were significantly (P<0.05) higher than cookies produced with 100% wheat flour. Highest copper content of 28.076mg/100g, calcium 3869.720mg/100g, magnesium 197.958mg/100g and iron 135.366mg/100g were observed in cookies enriched with 20% defatted, 15% defatted, 15% cooked and 5% roasted sesame seed flours, respectively. Calcium, magnesium and iron were the predominant minerals observed and lastly zinc. Increase in mineral content of cookies with soy-flour substitution had been reported by Ndife *et al.* [49]. Calcium (Ca) is an important bone related macro element in human nutrition [50]. The formulated cookies have better calcium (Ca) content and it's in agreement with the work of Ndife *et al.* [49]. According to MOH [51], the blended cookies could be estimated to fulfill about 21.2 – 48.7% of the required Calcium Recommended Daily Allowance (1000mg) for lactating mothers. Calcium in addition with other micro minerals and protein can help in bone formation with calcium acting as principal contributor [52]. Calcium is important in blood clotting, muscles contraction and in certain enzymes in metabolic processes [53]. Magnesium is an essential micronutrient needed for nervous system health [54]. Inadequate intakes of micronutrients (zinc and iron) have been associated with severe malnutrition, increased disease conditions and mental impairment [55]. The mineral content of all the composite cookies were significantly higher than the control (100% wheat flour). The results from this study revealed that the cookie samples would contribute substantially to the recommended dietary requirements for minerals [56].

3.3. Mineral Bioaccessibility of Cookies Produced from Wheat/Processed Sesame Seed Flour Blends

Table 4. Mineral Bioaccessibility of Cookies Produced from Wheat/Processed Sesame Seed Flour Blends

Cookies	Zinc	Copper	Calcium	Magnesium	Iron
WRSC1	66.168^{l}	70.203^{d}	32.601^{o}	61.581^{c}	78.302^{m}
WRSC2	91.693^{b}	65.275^{e}	36.737^{n}	60.030^{d}	81.325^{l}
WRSC3	86.137^{e}	59.805^{g}	74.569^{h}	58.240^{e}	93.512^{e}
WRSC4	70.042^{k}	75.233^{c}	71.551^{j}	57.818^{f}	83.843^{k}
WDSC1	89.190^{c}	15.077^{q}	84.358^{f}	54.905^{i}	89.916^{g}
WDSC2	97.378^{a}	43.228^{ij}	89.093^{d}	53.708^{j}	73.517^{n}
WDSC3	54.636^{n}	92.144a	25.054^{r}	55.735^{h}	53.445^{q}
WDSC4	40.601^{p}	43.948^{i}	30.885^{p}	54.746^{i}	33.526^{s}
WCSC1	52.958^{o}	18.443p	29.616^{q}	60.047^{d}	25.130^{t}
WCSC2	61.857^{m}	20.880^{o}	84.649^{f}	55.429^{h}	96.241^{c}
WCSC3	82.020^{f}	89.999b	97.677^{a}	88.122^{b}	86.995^{i}
WCSC4	86.349^{e}	36.141jk	67.282^{l}	89.815^{a}	64.794^{p}
WFSC1	74.163^{j}	28.861m	93.481^{c}	57.812^{f}	52.034^{r}
WFSC2	58.284^{m}	32.117^{l}	88.395^{e}	55.704^{h}	98.817^{a}
WFSC3	57.929^{mn}	26.763n	71.001^{jk}	56.481^{g}	94.939^{d}
WFSC4	74.994^{j}	13.664r	76.540^{g}	56.756^{g}	80.835^{l}
WGSC1	97.856^{a}	55.923h	73.167^{i}	56.623^{g}	97.904^{b}
WGSC2	88.202^{d}	60.126g	94.579^{b}	56.359^{g}	87.468^{h}
WGSC3	81.574^{g}	63.757f	67.133^{l}	56.235^{g}	93.040^{f}
WGSC4	76.330^{i}	33.954k	73.738^{hi}	50.922^{k}	85.712^{j}
WFC	77.020^{h}	29.541m	57.738^{m}	2.542^{l}	72.797^{o}

Values bearing different superscript in the same column differ significantly (P<0.05).
Key:
WRSC = Wheat:Roasted Sesame Cookies
Samples WRSC1, 2, 3 and 4 (95:5, 90:10, 85:15 and 80:20), respectively.
WDSC = Wheat:Defatted Sesame Cookies
Samples WDSC1, 2, 3 and 4 (95:5, 90:10, 85:15 and 80:20), respectively.
WCSC = Wheat:Cooked Sesame Cookies
Samples WCSC1, 2, 3 and 4 (95:5, 90:10, 85:15 and 80:20), respectively.
WFSC = Wheat:Fermented Sesame Cookies
Samples WFSC1, 2, 3 and 4 (95:5, 90:10, 85:15 and 80:20), respectively.
WGSC = Wheat:Germinated Sesame Cookies
Samples WGSC1, 2, 3 and 4 (95:5, 90:10, 85:15 and 80:20), respectively.
WFC = Wheat Flour Cookies 100%

Bioaccessibility of a mineral is the fraction of ingested minerals that is available for utilization in normal physical functions and storage. Mineral bioaccessibility in cookies produced from wheat in composite with processed sesame seed flour is presented in Table 4. Percentage mineral bioaccessibility ranged from 40.60 – 97.856%, 15.077 – 92.144%, 25.054 – 97.677%, 2.542 – 89.815% and 25.13 – 98.817% for Zn, Cu, Ca, Mg and Fe, respectively. Bioaccessibility of minerals in the cookies samples increased significantly (P<0.05) with increased percentage substitution of cooked and roasted sesame seed flour. While the mineral bioacceessibility decreased significantly with increase percentage substitution of defatted and germinated sesame seed flour. Bioacceessibility of iron is shown to increase with increase substitution of fermented sesame seed flour. Highest bioaccessible zinc (97.856%), calcium (97.677%), magnesium (89.815%) and iron (98.817%) were shown in cookies substituted with 20% germinated, 15% cooked, 20% cooked and 10% fermented sesame seed flours, respectively. Bioaccessibility of magnesium observed in wheat/processed sesame cookies were significantly (P<0.05) higher than those of the control (100% wheat flour). The role of cookies as source of minerals depend on the amount of minerals that is available for absorption, which is also known as bioaccessibility. Bioaccessibility has been defined as the fraction of a compound that is released from its matrix in the gastrointestinal tract and thus becomes available for intestinal absorption (i.e., enters the blood stream) [57]. Bioaccessibility includes the entire sequence of events that take place during the digestive transformation of food into material that can be assimilated by the body, the absorption/assimilation into the cells of the intestinal epithelium and lastly, the presystemic metabolism (both intestinal and hepatic) [58]. Digestibility of nuts and oilseed are reported to increase by roasting, this might be responsible for the release and increment in some mineral content [59]. Mineral Bioavailability refers to how well a nutrient can be absorbed by the body and used to reduce micronutrient malnutrition. Mineral bioavailability can be affected by the presence of the anti-nutritional factors such as phaytate, tannins and polyphenols in foods [21]. The two most important techniques used to improve mineral bioavailability are reducing the phytate content in the foods or adding extra minerals in the fortification and blending process [23,22]. According to Yang and Tsou [60], the study on iron bioavailability of vegetables indicated that cooking increases iron bioavailability of certain vegetables up to 2 to 10 times. The cooking enhancing effect can be achieved with different heating processes. Calcium can also inhibit iron absorption when fed as inorganic calcium compounds or when consumed in dairy products such as milk or cheese; the level of inhibition depends on the quantity of calcium consumed [61].

3.4. Mineral Balance of Cookies Produced from Wheat/Processed Sesame Seed Flour Blends

Table 5. Mineral Balance (%) of Cookies Produced from Wheat/Processed Sesame Seed Flour Blends

Cookies	Zinc	Copper	Calcium	Magnesium	Iron
WRSC1	33.832^{f}	29.797^{p}	67.399^{c}	36.419^{i}	21.698^{g}
WRSC2	8.307^{q}	34.725^{o}	63.263^{d}	39.971^{h}	18.675^{i}
WRSC3	13.863^{n}	40.195^{m}	25.431^{i}	41.760^{g}	6.488^{o}
WRSC4	29.958^{g}	24.768^{q}	28.449^{g}	42.182^{g}	16.157^{j}
WDSC1	10.810^{p}	84.923^{b}	15.642^{k}	45.095^{d}	10.084^{n}
WDSC2	2.622^{r}	56.772^{k}	10.907^{m}	46.292^{c}	26.483^{f}
WDSC3	45.364^{c}	7.856^{s}	74.946^{a}	44.265^{e}	46.555^{d}
WDSC4	59.399^{a}	56.052^{k}	69.115^{b}	45.254^{d}	66.474^{b}
WCSC1	47.042^{b}	81.557^{c}	70.384^{b}	39.953^{h}	74.870^{a}
WCSC2	38.144^{e}	79.120^{d}	15.351^{k}	44.571^{e}	3.759^{q}
WCSC3	17.980^{m}	10.001^{r}	2.323^{p}	11.878^{j}	13.005^{l}
WCSC4	13.651^{n}	63.859^{j}	32.718^{f}	10.185^{k}	35.206^{e}
WFSC1	25.837^{h}	71.139^{f}	6.519^{n}	42.188g	47.966^{c}
WFSC2	41.716^{d}	67.883^{h}	11.605^{l}	44.296e	1.183^{s}
WFSC3	42.071^{d}	73.237^{e}	28.999^{g}	43.519^{f}	5.061^{p}
WFSC4	25.006^{i}	86.336^{a}	23.460^{j}	43.244^{fg}	19.165^{h}
WGSC1	2.144^{r}	44.078^{l}	26.833^{h}	43.677^{f}	2.096^{r}
WGSC2	11.799^{o}	39.874^{m}	5.421^{o}	43.641^{f}	12.532^{m}
WGSC3	18.426^{l}	36.243^{n}	32.867^{f}	43.765^{f}	6.966^{o}
WGSC4	23.670^{j}	66.046^{i}	26.262^{h}	49.078^{b}	14.288^{k}
WFC	22.976^{k}	70.459^{g}	42.262^{e}	97.458^{a}	27.203^{f}

Values bearing different superscript in the same column differ significantly ($P<0.05$).

Key:

WRSC = Wheat:Roasted Sesame Cookies
Samples WRSC1, 2, 3 and 4 (95:5, 90:10, 85:15 and 80:20), respectively.
WDSC = Wheat:Defatted Sesame Cookies
Samples WDSC1, 2, 3 and 4 (95:5, 90:10, 85:15 and 80:20), respectively.
WCSC = Wheat:Cooked Sesame Cookies
Samples WCSC1, 2, 3 and 4 (95:5, 90:10, 85:15 and 80:20), respectively.
WFSC = Wheat:Fermented Sesame Cookies
Samples WFSC1, 2, 3 and 4 (95:5, 90:10, 85:15 and 80:20), respectively.
WGSC = Wheat:Germinated Sesame Cookies
Samples WGSC1, 2, 3 and 4 (95:5, 90:10, 85:15 and 80:20), respectively.
WFC = Wheat Flour Cookies 100%

The mineral balance in a food matrix is the insoluble mineral that is unavailable and cannot be absorbed. Result for mineral balance of cookies produced from wheat and sesame seed flour blends is shown in Table 5. Mineral balance for Zn, Cu, Ca, Mg and Fe ranged from 2.144 – 59.399%, 7.856 – 86.336%, 2.32 – 74.946%, 39.955 – 97.548 and 3.759 – 74.87%, respectively. Cookies with high mineral balance is an indication of low bioaccessibility of that specific mineral. Anti-nutritional factors are shown to cause complexing, inhibition and binding of minerals [21], thereby increasing the mineral balance and decreasing their bioaccessibility.

4. Conclusions

The study revealed that processing methods such as cooking, roasting, germination and fermentation significantly reduced the anti-nutritional components (phytate, oxalate and total phenol) of the flour blends. Total mineral content of cookies produced from processed sesame seed blends with wheat increased significantly than cookies produced from 100% wheat flour. Bioaccessibility of minerals in the cookie samples also increased significantly with increased percentage substitution of cooked and roasted sesame seed flour. Cookies with 5% fermented sesame seed flour substitution recorded highest percentage bioaccessible zinc and magnesium. Cookies with high mineral balance is an indication of low bioaccessibility of that specific mineral component.

REFERENCES

[1] Singh R., Singh G. and Chauhan G.S (2000). Nutritional evaluation of soy fortified biscuits. *Journal of Food Science and Technology*, 37, 162-164.

[2] Albert R.D. (1999). Bakery materials and methods 4th ed. Macmillan Publishers, London.

[3] Chinma C.E., James S., Imam H., Ocheme O.B., Anuonye J.C. and Yakubu C.M. (2011). Physicochemical and Sensory Properties, and In-Vitro Digestibility of Biscuits Made from Blends of Tigernut (*Cyperus esculentus*) and Pigeon Pea (*Cajanus cajan*). *Nigerian Journal of Nutritional Science*, 32, 52-62.

[4] Ebere C.O., Emelike N.J.T. and Kiin-Kabari D.B. (2015). Physicochemical and sensory properties of cookies prepared from wheat flour and cashew-apple residue as a source of fibre. *Asian Journal of Agriculture and Food Science*, 3(2), 213-218.

[5] Emelike N.J.T., Uwa F.O., Ebere C.O. and Kiin-Kabari D.B. (2015a). Effect of drying methods on the physico-chemical and sensory properties of cookies fortified with Moringa (*Moringa oleifera*) leaves. *Asian Journal of Agriculture and Food Sciences*, 3(4), 361-367.

[6] Kiin-Kabari D.B., Emelike N.J.T. and Ebere C.O. (2017a). Influence of drying techniques on the quality characteristics of wheat flour cookies enriched with moringa (*Moringa oleifera*) leaf powder. *International Journal of Food Science and Nutrition*, 2(3), 94-99.

[7] Olayanju T.M.A., Akinoso R. and Oresanya M.O. (2006). Effect of wormshaft speed, moisture content and variety on oil recovery from expelled beniseed. *Agricultural Engineering International*, 8, 1-7.

[8] Naturland. (2002) Organic farming in the Tropics and Subtropics: Sesame. 21/07/11. Available at www.naturland.de/fileadmin/MDB/documents/Publication/English/sesame.pdf.

[9] Kahyaoglu T. and Kaya S. (2006). Modeling of moisture, color and texture changes in sesame seeds during the conventional roasting. *Journal of Food Engineering*, 75(2), 167-177. https://doi.org/10.1016/j.jfoodeng.2005.04.011.

[10] Bamigboye A.Y., Okafor A.C. and Adepoju O.T. (2010). Proximate and mineral composition of whole and dehulled Nigerian sesame seed. *African Journal of Food Science and Technology*, 1(3), 71-5.

[11] RMRDC (2004). Raw Material Research and Development Council. Survey Report of ten Selected Agro-Raw materials in Nigeria. October, pp 1-4.

[12] Chemonics International Inc. (2002). *Overview of the Nigerian Sesame Industry*. The United States Agency for International Development (USAID)/Nigeria RAISE IQC Contract No. PCE-I-00-99-00003-00.

[13] Global AgriSystems (2010). Dehulled and roasted sesame seed oil processing unit. 18/08/11. Available at http://mpstateagro.nic.in/Project%20Reports.

[14] Kumar V., Sinha A.K., Makkar H.P.S. and Becker K. (2010). Dietary roles of phytate and phytase in human nutrition: a review. *Food Chemistry*, 120(4), 954-959. https://doi.org/10.1016/j.foodchem.2009.11.052.

[15] Steinkraus K.H. (1992). Lactic Acid Fermentations, in "Applications of biotechnology to traditional fermented Foods". A report of an Ad Hoc panel of the Board on Science and Technology for International Development, National Academy Press, Washington D.C., USA.

[16] Achinewhu S.C. (1986). The effect of fermentation on carbohydrate and fatty acid composition of African oil bean seed (*Pentaclethra macrophylla*). *Food Chemistry*, 19(2), 105-116. https://doi.org/10.1016/0308-8146(86)90104-4.

[17] Enujiugha V.N, Amadi, C.O and Sanni, T.M. (2002). α-Amylases in raw and fermented African oil bean seeds (*Pentaclethra macrophylla Benth*). *European Food Research. and Technology*, 214(6), 497-500. Doi: 10.1007/s00217-001-0461-2.

[18] Sangronis E. and Machado C.J. (2007). Influence of Germination on the Nutritional Quality of *Phaseolus vulgaris* and *Cajanus cajan*. *LWT-Food Science and Technology*, 40, 116-120.

[19] Makinde F.M. and Adebile T.V. (2018). Changes in Nutritional, Functional and Pasting Properties of Raw and Germinated. *Acta Scientific Nutritional Health*, 2(11), 7-15.

[20] Parada J. and Aguilera J.M. (2007). Food Microstructure Affects the Bioavailability of Several Nutrients. *Journal of Food Science*, 72(2), 21-32. Doi: 10.1111/j.1750-3841.2007.00274.x.

[21] Gashaw M.T., Abebe H. and Esayas K. (2015). Bioavailability of minerals in cookies developed from blend of moringa leaf powder and wheat flour for iron deficient lactating mothers. *International Journal of Food Science and Nutrition Engineering*, 5(6), 226-232.

[22] Kayode A.P. (2006). Diversity, Users" Perception and Food Processing of Sorghum: Implications for Dietary Iron and Zinc Supply. Ph.D. thesis Wageningen University, Wageningen, Netherlands. pp. 11-15.

[23] Welch R.M. (2005). Deficiencies of Micronutrients. *Food Nutrition Bullet*, 26, 419-421.

[24] Ejigui J., Savoie L., Marin J. and Desrosiers T. (2005). Influence of traditional processing methods on the nutritional composition and anti-nutritional factors of red peanuts (*Arachis hypogea*) and small red kidney beans (*Phaseolus vulgaris*). *Journal of Biological Science*, 5(5), 97-605. Doi: 10.3923/jbs.2005.597.605.

[25] Kanu P.J., Kanu J.B., Sandy E.H., Kandeh J.B.A., Mornya P.M.P. and Huiming Z. (2009). Optimization of enzymatic hydrolysis of defatted sesame flour by different proteases and their effect on the functional properties of the resulting protein hydrolysate. *American Journal of Food Technology*, 4(6), 226-240. Doi: 10.3923/ajft.2009.226.240.

[26] Martín-Cabrejas M.A., Aguilera Y., Pedrosa M.M., Cuadrado C., Hernandez T., Diaz S. and Esteban R.M. (2009). The impact ofdehydration process on anti-nutrients and protein digestibility of some legume flours. *Food Chemistry*, 114(13), 1063-1068.

[27] Giami S.Y., Chibor B.S., Edebiri K.E. and Achinewhu S.C. (1999). Changes in Nitrogenous and Other Chemical Constituents, Protein Fractions and In-Vitro Protein Digestibility of Germinated Fluted Pumpkin (*Telfairia occidentalis* Hook) Seed. *Plant Foods for Human Nutrition*, 53, 333-342.

[28] Francis G., Makkar H.P.S. and Becker K. (2001). Antinutritional factors present in plant-derived alternate fish feed ingredients and their effects in fish. *Aquaculture*, 199(3-4), 197-227. https://doi.org/10.1016/S0044-8486(01)00526-9.

[29] Grant G. (1991). Lectins. In: "Toxic Substances in Crop Plants" ed. by F.J.P. D'Mello, C.M. Duffus and J.H.Z. Duffus. The Royal Society of Chemistry, Thomas Graham House, Science Park, Cambridge CB4 4WF, Cambridge, pp. 49-67.

[30] Shahidi F. (1997). Beneficial Health Effects and Drawbacks of Anti-Nutrients and Phytochemicals in Foods. In: "Antinutrients and Phytochemicals in Food" ed. By F. Shahidi. Washington, DC: American Chemists Society, pp. 1-10.

[31] Makinde F.M. and Akinoso R. (2014). Comparison between the nutritional quality of flour obtained from raw, roasted and fermented sesame (*Sesamum indicum L.*) seed grown in Nigeria. *Acta Scientiarum Polonorum, Technollogia Alimentaria*, 13(3), 309-319. Doi: 10.17306/J.AFS.2014.3.9.

[32] Mukhopadhyay R. (2001). Effect of fermentation on the nutritive value of sesame seed meal in the diets for rohu, Labeo rohita (Hamilton), fingerlings. *Aquaculture Nutrition*, 5(4), 229-236. Doi: 10.1046/j.1365-2095.1999.00101.x.

[33] Jirapa P., Normah H., Zamaliah M.M., Asmah R. and Mohamad K. (2001). Nutritional quality of germinated cowpea flour (*Vigna unguiculata*) and its application in home prepared weaning foods. *Plant Foods for Human Nutrition*, 56(3), 203-216. Doi: 10.1023/a:1011142512750.

[34] Yagoub A.A. and Abdalla A.A. (2007). Effect of domestic processing methods on chemical composition, in vitro digestibility of protein and starch and functional properties of bambara groundnut (*Voandzeia subterranea*) seed. *Research Journal of Agriculture and Biological Sciences*, 3(1), 24-34.

[35] Mohamed E., Souhail B., Olivier R., Christophe B. and Hamadi A. (2007). Quality characteristics of sesame seeds and by-products. *Food Chemistry*, 103(2), 641-650.

[36] Emelike N.J.T., Barber L.I. and Ebere C.O. (2015b). Proximate, mineral and functional properties of defatted and undefatted cashew (*Anacardium occidentale Linn.*) kernel flour. *European Journal of Food Science and Technology*, 3(4), 11-19.

[37] Akindahunsi A.A. (2004). Physicochemical studies on African oil bean (*Pentaclethra macrophylla*) seed. *Journal of Food, Agriculture and Environment*, 2(3-4), 14-17.

[38] Okoli E.C. and Adeyemi I.A. (1989). Manufacturing of ogi from malted (germinated) corn (*Zea mays*). Evaluation of chemical, pasting and sensory properties. *Journal of Food Science*, 54(4), 971-973. https://doi.org/10.1111/j.1365-2621.1989.tb07924.x.

[39] Hassan E.E. (2011). Effect of heat treatments on certain antinutrients and in vitro protein digestibility of peanut and sesame seeds. *Food Science and Technology Research*, 17(1), 31-38. Doi: 10.3136/fstr.17.31.

[40] Singleton V.L., Draper D.E. and Rossi J.A. (1966). Paper chromatography of phenolic compounds from grades, particularly seeds and some variety ripeness relationship. *American Journal of Enology and Viticulture*, 17, 206-217.

[41] AOAC (2012). Association Of official Analytical Chemists. Official Methods of Analysis, 19th Edition Washington, DC USA.

[42] Aliyu H.N. and Sani U. (2009). Production of biscuit from composite flour as a substitute for wheat. *Bioscience Research Communications*, 21(3), 129-32.

[43] Luten J., Crews H., Flynn A., Van Dael P., Kastenmayer P., Hurrell R. and Frohlich W. (1996). Interlaboratory trial on the determination of the in vitro iron dialysability from food. *Journal of the Science of Food and Agriculture*, 72(4), 415-424.

[44] Habiba R.A. (2002). Changes in anti-nutrients, protein solubility, digestibility, and HCl-extractability of ash and phosphorus in vegetable peas as affected by cooking methods. *Food Chemistry*, 77(2), 187-192. https://doi.org/10.1016/S0308-8146(01)00335-1.

[45] Fagbemi T.N., Oshodi A.A. and Ipinmoroti K.O. (2005). Processing effects on some antinutritional factors and In vitro multienzyme protein digestibility (IVPD) of three tropical seeds: breadnut (*Artocarpus altilis*), cashew nut (*Anacardium occidentale*) and fluted pumpkin (*Telfairia occidentalis*). *Pakistan Journal of Nutrition*, 4, 250-256.

[46] Frontela C., Garcia-Alonso F.J., Ros G. and Martinez C. (2008). Phytic acid and inositol phosphates in raw flours and infant cereals: the effect of processing. *Journal of Food Composition and Analysis*, 21(4), 343-350. Doi: 10.1016/j.jfca.2008.02.003.

[47] Wang N., Hatcher D.W. and Gawalko E.J. (2008). Effect of variety and processing on nutrients and certain anti-nutrients in field peas (*Pisum sativum*). *Food Chemistry*, 111(1), 132-138. https://doi.org/10.1016/j.foodchem.2008.03.047.

[48] Siddhuraju P. and Becker K. (2001). Effect of various domestic processing methods on anti-nutrients and in vitro-protein and starch digestibility of two indigenous varieties of Indian pulses, Mucuna pruries var utilis. *Journal of Agricucltural and Food Chemistry*, 49(6), 3058-3067. Doi: 10.1021/jf001453q.

[49] Ndife J.1., Fatima K. and Stephen F. (2014). Production and quality assessment of enriched cookies from whole wheat and full fat soya. *European Journal of Food Science and Technology*, 2(1), 19-28.

[50] Soetan K.O., Olaiya C.O. and Oyewole O.E. (2010). The importance of mineral elements for humans, domestic animals and plants: a review. *African Journal of Food Science*, 4(5), 200-222.

[51] MOH (Ministry of Health) (2006). Food and Nutrition Guidelines for Healthy Pregnant and Breastfeeding Women: A Background Paper. Wellington, New Zealand. 200p.

[52] Kiin-Kabari D.B., Hart A.D. and Nyeche P.T. (2017b). Nutritional composition of selected shellfish consumed in Rivers State, Nigeria. *American Journal of Food and Nutrition*, 5(4), 142-146.

[53] Davies I.C. and Jamabo N.A. (2016). Determination of mineral contents of edible parts of shellfishes from Okpoka Creeks in Rivers State, Nigeria. *International Journal of Fisheries and Aquaculture Research,* 2(2), 10-18.

[54] Abulude F.O., Lqual L.O., Ehikharmery G., Adesanya W.O. and Ashafa S.L. (2006). Chemical composition and functional properties of some pours from the Coastal Area of Ondo State, Nigeria. *Journal of Environmental, Agriculture and Food Chemistry*, 5, 1235-1240.

[55] Mannay S. and Shadaksharaswany C.M. (2005). Foods: Facts and Principles. (2nd ed.). New Age International Ltd. Publishers. New Delhi, India.

[56] Wardlaw G.M. (2004). Perspectives in Nutrition. (6th ed.). McGram Hill Companies, New York, U.S.A.

[57] Benito P. and Miller D. (1998). Iron absorption and bioavailability: an updated review. *Nutrition Research*, 18(3), 581-603.

[58] Ting R.S. and Loh S.P. (2016). In vitro bioaccessibility of calcium, iron and zinc from breads and bread spreads. *International Food Research Journal*, 23(5), 2175-2180.

[59] Mohini S. and Eram S.R. (2005). Food Science Experiments and Applications. CBS Publishers, 161:22-27.

[60] Yang R.Y. and Tsou S.C. (2006). Enhancing iron bioavailability of vegetables through proper preparation principles and applications. *Journal of International Cooperation*, 1(1), 107-119.

[61] Yang R.Y., Lien C. C., Jenn C. H., Brian B. C., Manuel C. P., Chadha M. L. and Virginie L. (2006). Nutritional and Functional Properties of Moringa Leaves−From Germplasm, to Plant, to Food, to Health. Moringa and Other Highly Nutritious Plant Resources: Strategies, Standards and Markets for a Better Impact on Nutrition in Africa. Accra, Ghana. 16-18 November, 2006 workshop; 44p.