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Chemical composition, functional and phytochemical properties of black, brown and white varieties of Nigerian sesame seeds

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--ABSTRACT--
The comparative studies of the physicochemical and functional properties of black, brown and white (local and improved varieties) of sesame seeds grown in Nigeria were carried out. The Physicochemical and functional properties were determined using standard analytical methods of AOAC. The results indicated that the physicochemical and functional properties varied with colors of the seeds. The physical analysis for the appearance of 1000 seed weight, seed volume and true density for black, brown and white ranged from 0.92-2.91, 3.13-10.56 and 0.22-0.31 respectively. The values for proximate analysis ranged from 2.82-4.5%, 19.67-28.42%, 8.23-31.12% 87-48.02%, 7.32-20.42 %, 3.43-5.37% for moisture, protein, fibre, fat, ash and carbohydrate contents respectively. The mineral analysis of the samples revealed that the potassium was dominant among the macro minerals while Manganese was the highest among the micro minerals in the samples. The phytochemicals analysis showed that oxalates, phytates, tannins, phenols and flavonoids had values ranging from 0.43- 0.96 mg/100g, 0.11-0.27 mg/100g, 7.8- 9.07 mg/100g, 1.10-1.69 mg/100g and 2.01-2.45 mg/100g respectively. The functional properties had values ranging from 0.47-0.93 g/ml, 1.2-1.67 g/ml, 0.83-1.56 g/ml, 49.00-50.00 % and 4.00-12.00 % for bulk density, water absorption capacities, oil absorption capacities, emulsion capacity, foam capacity and foam stability respectively. The study conclude that sesame seeds have diverse nutrient contents which is greatly dependent on the colour of the seeds and an understanding of this fact would help in the design of appropriate formulation strategies for the resulting products.
KEYWORDS: *Sesame seed varieties, seed colour, food formulation, nutritional properties*

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I. INTRODUCTION

Sesame (*Sesamum indicum L.*) is an oil seed that belongs to the family *pedaliaceae,* genus *sesamum* and specie *indicum*. Sesame is known by different names in different locations. In Nigeria, it is known as Benni seed, as it is believed to originate from the Benue valley. The observable seed color range from black to white. The preference for colour of sesame seeds differs from region to region although, the demand for white colour is 30% higher [1] [2]. The physical appearance of seed color is a major marketing factor and acceptability and market value varies greatly with cultural preferences. Mainly, larger seed size, coupled with a light colored seed coat determines the market price.

Sesame seed is called the *queen* of the oil seed crops because of its high oil yield, mildness and pleasant taste [3] [4]. Nigeria is one of the major producer and exporter of sesame seeds and ranked 6th among sesame producing countries in Africa [5]. The production of sesame seeds in Nigeria is concentrated in the middle belt (Benue State) and production is expected to boost due to its enormous uses and high foreign exchange earned from its export [6]. There are great diversity in the sesame germplasm for the different desirable traits such as plant height, branching pattern, leaf shape, number of capsules per axil, number of seeds per capsule, 1000 seed weight, oil content, seed color, resistance to pest and diseases. Genetic diversity depends on the nativity or regions of the crop and genetic effects [3][7].

The diversity of sesame in other parts of the world like India has been documented, but that of the Nigerian sesame is not yet fully established and above all, its rich nutrients are believed to be underutilized in

Nigeria. Identification and use of desirable physico-chemical and functional properties of Nigerian sesame seeds has become more relevant these days because of its use and different applications in the food industries. Sesame is cultivated for its flavorsome, edible seed and high quality oil and protein source [8] [9]. Sesame seed contains high oil content (46% - 50%) with 83% - 90% unsaturated fatty acids, mainly linoleic acid (37% - 47%), oleic acid (35% - 43%), palmitic (9% - 11%) and stearic acid (5% - 10%) with trace amount of linolenic acid [8] [10]. The seed contains 20% proteins in its native form and various minor nutrients such as vitamins and minerals, large amount of characteristic lignans (methylenedioxyphenyl compounds) such as sesamin, sesamol, sesamolin and tocopherols [3] [11].

The functional components together impart resistance against oxidative deterioration and provide nutraceutical value to the crop. Therefore, sesame seeds with high amounts of nutritional components are consumed as a traditional health food for its specific antihypertensive effect, anti-carcinogenic, anti-inflammatory, bioactive compounds including phenolics, phytosterols, phytates, polyunsaturated fatty acids and short chain peptides [12]. Sesame seeds have special significance for human nutrition on account of its high content of sulphur amino acids and phytosterols. It has a high protein concentration which is rich in methionine, cysteine and tryptophan. Since these amino acids are missing from a number of other sources of vegetable protein, such as soya, sesame meal or flour can be added to recipes to give a better nutritional balance to health food products thus complementing most oil seeds and vegetable proteins very well. Their many health promoting effects have been attributed to a group of compounds called lignans [13].

The antioxidative agents (sesamin, sesamolin, sesamol and sesaminol glucosides along with tocopherol make the oil highly stable and therefore have a long shelf life [14] [8]. Among the vitamins in the sesame seed, the presence ofvitamin E is very interesting in relation to the effectiveness of sesame seed as a health food. Sesame seeds are a rich source of phytates however, the high content of phytic and oxalic acids in sesame seed hinders the use of sesame protein as food [15]. The nutritional benefits derived from sesame seeds are based on the variety being utilized and the information regarding the variety of sesame seeds as it affects the nutritional components are scarce in the literature. The objective of this study is to determine the physicochemical and functional properties of Nigerian sesame seed coat colors (black, brown and white). The scientific information generated from this research could serve as an important input for production, marketing and utilization for the benefit of sesame growing areas.

II. MATERIALS AND METHODS

Source of raw materials and reagents

White Sesame seeds were obtained from north bank market in Makurdi of Benue state, Nigeria black sesame seeds were obtained from Jos Main market of plateau state and brown sesame seeds were obtained from Wamba market in Nasarawa state, Nigeria. The sesame seeds were all identified at the college of Agronomy, University of Agriculture Makurdi. All analytical reagents and chemicals that were used in this study were of standardized grade.

Physical analysis

One thousand (1000) seed weights, volume, true density, colour/appearance were determined by the method reported by [16]

Determination of proximate composition and energy values

The proximate composition (Moisture, crude fat, crude fibre, protein and carbohydrate contents of the samples were determined using the method of [17], while the energy value was calculated using the Atwater's conversion factor (4 x % Protein + 9x % Fat + 4 x % Carbohydrate) expressed in kcal/100g as reported by All the analyses were carried out in triplicate.

Mineral Composition

The mineral composition of the samples was analyzed by dry ashing the sample at 550 ºC to constant weight and dissolving the ash in 100 ml standard flask using distilled deionized water with 3 ml of 3 M HCl. Sodium and potassium were determined by using a flame photometer (model 405, corning, U.K). All other minerals were determined by Atomic Absorption Spectrophotometer [18].

Phytochemical properties

Standard analytical procedures were used for the evaluation of the phytochemical properties of the samples. The oxalate was calculated using the method described by [19] tannin content was determined using the method of [20]. Phytate content was determined using the colorimetric method described by [21], polyphenolic content was determined using the method of [22] and flavonoid content was determined using the standard method of [23].

Functional Properties
The bulk densities of the samples were determined using the method of [24], water absorption capacities were evaluated using the method described by [25],oil absorption capacities were determined by the method of emulsion capacities and stability indices were determined using the methods described by [25],while the foaming properties were evaluated using the protocols described by [26].

Statistical Analyses
The data obtained in the analysis were subjected to Analysis of Variance (ANOVA) and the means were separated using Duncan multiple range test. Values reported are means ± standard deviation of triplicate determinations. Mean values with different superscripts within the same column are significantly ($P < 0.05$) different.

III. Results and Discussion

Physical properties of black, brown and white sesame seeds

Data concerning the physical properties of agricultural food materials are of importance to plant breeders, engineers, machine manufactures, food scientists, processors and consumers. Those properties include 1000 seed weight, true density etc. are useful in postharvest unit operations for the design of cleaning, grading, sorting, transportation, handling, aeration, sizing, storing, size reduction, packaging and other processing equipment[27].The quality of sesame seeds is influenced by their physical characteristics which are of extreme importance in the entire production chain [15]**.** Results of the physical analysis are presented in Table 1. The results indicated significant variations at $p \leq 0.05$ in the physical parameters (1000 seed weight and volume, specific density and appearance) measured among the sesame seed colors.

Sesame seeds analyzed were tiny, flat, oval with a nutty taste and delicate with color variations between black, brown and the white. The seeds from Jos main market were black local small size and improved black bigger size. The seeds from Wamba market in Nasarawa State were brown in color (BRL and BRI) and the BRL smaller in size than the BRI. Sesame seeds from North bank in Makurdi Benue State were white in colour (WL and WI). Previous studies have shown that brown seeds are grown in Kano, Jigawa, Katsina, Nasarawa and Lagos States [28]. White sesame seeds are grown in Keffi, Lafia, Makurdi, Doma of Nasarawa,Benue, and Taraba States respectively. [12] also reported color variations in sesame seed between white, yellow reddish brown and black. The seed coat color of sesame seeds is said to be associated with seed biochemical properties, levels of antioxidant content and activity, level of disease resistance and a marker of evolution within the sesamum genus [29] [30]. The preference for sesame color varies from region to region and cultural preferences, although there is general higher demand for high yielding white seeded variety with good oil content. White sesame seeds are food grade used in the baking industry. Brown seed are primarily oil grade seeds while and the black sesame seeds are preferable for use of medical conditions. The physical appearance of seed color is a major marketing factor that determines the acceptability and market value of sesame types and varieties.

Dark colored seeds attract less value and marketable products. In Nigeria and in India, white sesame seeds are sold at a price at least 30% higher than that of brown or black seeds because of consumers preference and greater culinary utilization [31]. Flavanoids, anthocyanins and Lignans have been reported to play an important role in emerging discernible color variation and seed coat color development [32]. The average values for 1000 seed weight ranged between 0.92g to 2.91g with those of white improved variety having the highest (2.91g) and the black local having the least value(0.92g). This value is approximately equal to the recommended weight for export of 3.0g. This result contrasts with that of [15] who reported higher 1000 seed weight for black seeds (2.7) as compared to the white seeds. These values are however, similar to those reported by which were 2.74- 3.16 and 2.0 -3.5, respectively. These variations could be as a result of variety and cultural conditions and stage off maturity. True density values ranged from0.22 – 0.31g/ml^3 for BLL and WWL. However, there was no significant difference between the samples except sample WL.

The physical properties of sesame seeds play an important role in problems associated with design or development of sieve unit, a specific machine, handling, cleaning and storage. Information on true density is used to design sesame separation or cleaning process. In order to enable the best possible conditions for seed processing, storing and transportation, information on their physical characteristics are needed. The important characteristics required in design and development of processing equipment are size, shape, bulk density, specific gravity, porosity, static coefficient of friction, angle of repose, rheological properties etc.

Proximate Composition of Black, Brown and White Sesame.

Chemically, foods are composed mainly of water, lipids, proteins, and carbohydrates with small proportions of minerals and organic compounds. Minerals are salts, and organic substances are vitamins, emulsifiers, acids, antioxidants, pigments, polyphenols, flavors, [33]. The results of proximate analysis of sesame seeds is presented in Table 2. The result showed significant differences at $p \leq 0.05$ among the three colors of sesame seeds evaluated. The results of proximate analysis reveal that sesame seeds are rich in nutrients and are a good source of nutrients for human and animal consumption. The present results are similar to those obtained by [34]. The moisture values ranged from 2.82 % for Wi and 4.50 % for BLL.

The values for the protein content ranged between 19.67 to 28.42 % for BLI and BRL respectively. The seeds are an also very valuable source of dietary proteins with fine quality amino acids that are essential for growth, especially in children. Just 100 g of seeds provide about 18 g of protein (32% of daily-recommended values). The values for fiber varied from 8.23-31.12 % for Wl and BLI respectively. The whole seed was found to be significantly higher ($p < 0.05$) in crude fibre compared with dehulled sample.

Fibre is important in the body as it helps to maintain good health by reducing blood cholesterol and Glucose level in the body. The fat content had values ranging from 25.87- 48.02 % for BLL and Wl. Ranges reported by other researchers include 43.20 to 54.60 % [28]. Variations in oil content could be due to variety, plant maturity, harvesting time soil type, climatic conditions and extraction methods used. The energy value ranged between 496.62- 609.92 kcal for BLL and WI respectively. Energy value is highly dependent on the fat content, protein content and carbohydrate content in the food.

Ash content ranged from 3.43-5.37% and these values were different compare with the 3.56 % - 6.26 % reported by [28]. High ash content indicates that sesame is a good source of minerals for nutrition in the body.

The carbohydrate content of the samples varied between 7.32- 20.42 %. These values are similar to those reported (16.83 to 43.83 %) by [28].

Mineral composition of black, brown and white sesame seeds

Vitamins and minerals help body grow, develop, and stay healthy. The body uses minerals to perform many different functions, from building strong bones to transmitting nerve impulses. Some minerals are even used to make hormones or maintain a normal heartbeat. Calcium for instance, helps build strong bones, so you can do everything from standing up straight to scoring that winning goal. It also helps build strong, healthy teeth, for chomping on tasty food. Similarly, the body needs iron to transport oxygen from your lungs to the rest of your body.

The results of mineral analysis of the sesame seeds is presented in Table 3. All data are the results of average of three measurements on each sample with a relative standard deviation of less than 10%. Fourteen elements (Na, K, Ca, Mg, P, Cl and S (macro elements); Mn, Cu, I, Zn, Fe, Fl, and N (micro elements) were detected. The results showed a similar pattern for the trace elements in sesame seeds from all the three colored sesame seeds. The white samples were richer in mineral content than the black and brown colors. These results also showed that the Nigerian sesame seeds are rich in essential minerals and trace elements that promote wellbeing in humans.

Minerals are unique nutrients because of their important role in metabolism. They are essential part of many important enzymes and they also play roles as catalysts and antioxidants. Iron and copper for example are essential in blood formation and copper is also involved in normal carbohydrateand lipid metabolism [8].

Chromium regulates the action of insulin and is also essential in carbohydrate and lipid

metabolism [35]. Zinc for its part is a multi-functional nutrient involved in glucose and lipid metabolism, hormone function and wound healingand is also associated with proper hair growth[36]. As shown in Table 3, at a daily consumption rate of 100 g/day, the values of all the elements in sesame seed fall within the US recommended Dietary Reference Intakes (DRIs)[37].

The seeds of sesame cultivars were found to be a rich source of certain minerals, particularly calcium, phosphorus, and iron. The highest recorded value was 1450mg/100 g in some Indian sesame cultivars [38] and the lowest Calcium value (228.3 mg/100 g) was reported in some Lebanese Sesame cultivars [28]. [16] reported whole and dehulled white variety of sesame seeds contain about 14.90 and 14.70%. The presence of greater amounts of calcium and oxalic acid may be due to calcium oxalate. However, calcium bound as oxalate salt is not biologically available, which is of prime importance in feeding of infants. [16]also reported that sesame is rich in protein, calcium, phosphorus and vitamins, seeds mixed with peanut and bengal gram flours is as effective as skimmed milk in controlling the clinical manifestation of malnutrition. Sesame flour supplemented with fish protein concentrate has a nutritive value similar to animal proteins. Sesame flour mixed with green gram has been effectively used to cure ‘Kwashiorkor’, a disease mostly found in infants of 1 to 4 years of age and is due to deficiency of proteins in diets [39]. Phosphorus content ranged between 540 to 640 mg/100 g in all the cultivars studied, while the results reported by [40] ranges from (540 to 640 mg/100g).

The values obtained for zinc in the samples were lower compared with the reported values in[41] [42]but in the same range of those reported by [43]. Such variations might be attributed to the difference in varieties, growth environment, pretreatment and analytical methods used.

The Recommended Dietary Allowance (RDA) in the U.S. for adults is 8-11 mg/day for Zn, 8-18 mg/day for Fe, 0.9 mg/day for Cu, 1.8-2.3 mg/day for Mn, 0.055 /day for Se (Food and Nutrition Board of the Institute of Medicine). The current RDA for children (4–8-year-old) is 5 mg/day for Zn, 10 mg/day for Fe, 0.44 mg/day for Cu, 1.5 mg/day for Mn, 0.03 mg/day for Se. The RDA for Barium is not available for the estimated average requirements cannot be developed. One hundred gram black or white sesame seeds can meet nearly 50% Zn, 40%- 90% Fe, 250% Cu, 85%-108% Mn and 30% Selenium for adults according to the suggested RDA. Many of these minerals have a vital role in bone mineralization, red blood cell production, enzyme synthesis, hormone production, as well as regulation of cardiac and skeletal muscle activities. Just a hand full of sesame a day provides enough recommended levels of phenolic antioxidants, minerals, vitamins and protein.

Phytochemical content of black, brown and white sesame seeds

Phytochemicals are great antioxidant potential and are of great interest due to their beneficial effects on health of human beings, and they give immense health benefits to the consumers. Epidemiological and animal trials suggest that the regular consumption of fruits, and vegetables, and whole grains reduces the risk of various diseases linked with oxidative damage [44] [45].

The results of the analysis of phytochemicals is presented in Table 4. The results showed no significant differences at $p > 0.05$. The values for oxalate content ranged from 0.43-0.96 % for BLI and WI, phytates content varied from 0.11- 0.27 % for BRL and BLI, Tannin contents ranged from 7.80 – 9.07 % for BRI, WI and BLI. Phytates content were maximum in black sesame than in the white and brown sesame seeds. The values for phenols varied between 1.10-1.69 % for BLI and WI. The flavonoids content ranged from 2.01- 2.46 µg/100g for BLI and BLL. The results revealed that tannins were highest, followed by flavonoids, phenols oxalates and phytates. These findings are different from those reported by[46], highest phenols in black sesame seeds. Oxalates affects calcium and magnesium metabolism and react with proteins to form complexes which have an inhibitory effect in peptic digestion.

Phytates or Phytic acid is an important source of plant phosphorous. Its six reactive phosphate groups have a strong chelating ability to complex with proteins in addition to minerals, thereby contributing to anti-nutritional effects.

Dietary phytates have attracted much interest because of their role in cancer prevention and hypocholesterolemic effect [47]. The action of phytates is linked with the antioxidant effect by which it binds the excess free iron, thus preventing the formation of free radicals. Sesame seeds are a rich source of phytates and in defatted sesame meal it is 5.18%, compared with 1% in soybean meal and 1.5% in isolated soybean protein. The high content of phytic acid and oxalic acid in sesame seed hinders the use of sesame protein as food [13].

Functional properties of black, brown and white sesame seeds.

Functional properties have been defined as "those physical and chemical properties that influence the behavior of proteins in food system during processing storage, cooking, and consumption" [48]. [49]reported the effect of pH and NaCl concentration on protein solubility, emulsifying and foaming properties of sesame protein concentrate. The least protein solubility (2.2%) occurred at pH 4. At above and below pH 4, solubility increased 6.6% at pH 2 and 13.1% at pH 10. The protein solubility of sesame protein concentration increased with increase in ionic strength, ranging from 9.8%.

The results of functional properties of sesame seeds are presented in Table 5. The results indicate variations in the functional properties of the samples but not significantly ($p>0.05$) different from one another. The values for bulk density ranged from 0.9-0.93 g/m^3 for BLL and WI, water absorption capacities; 1.2-1.67 g/m^3 for WI and BLI; oil absorption capacity; 0.83-1.56 g/m^3, for WI and BLI; emulsifying capacity index; 49.23- 50.00 BLI and BLL; foam capacity; 4.00-12.00 g/m^3 for BLL and WI and 25.00-60 BLL and BLI. Present study reveals higher values for foam stability followed by emulsifying capacity index which did not vary for all samples. The values for emulsifying capacity index are similar to those reported by [50].This finding suggests that they may be suitable for production of salad creams, Mayonnaise etc. The low values for water and oil absorption capacities suggest that they are not suitable for baking products that requires raising like bread, doughnuts muffins etc.

Functional properties are important in food processing, and food formulation depends on the type of food products in which the food is to be used. For example, sesame seeds with low oil and water holding capacity are not desirable for use in meat products, while the high emulsifying and foaming properties are good for salad dressing and soup [51] and also has potential for baby food fortification/formulation in food industries [52]. The sesame protein isolate (SPI) exhibited high oil and water absorption capacities, and could be employed in the formulations of food products such as doughnut, pancakes and baked food products and as food thickener. The extracted oil exhibited desirable physicochemical qualities of edible vegetable oil.

Table 1: Physical properties of black , brown and white sesame seeds

Sample /Parameter	1000SEED WEIGHT	1000 SEED VOLUME	SPECIFIC DENSITY	APPEARANCE

BLL	1.17 ± 0.02^{bac}	4.24 ± 0.02^{b}	0.27 ± 0.02b^{c}	Black small size
BLI	2.20 ± 0.03^{de}	7.09 ± 0.02^{d}	0.31 ± 0.02^{f}	Black big size
BRL	0.92 ± 0.06^{ab}	3.13 ± 0.02^{a}	0.29 ± 0.02^{dceb}	Brown
BRI	1.51 ± 0.11^{cab}	4.98 ± 0.02^{c}	0.30 ± 0.02^{ebc}	Brown
WL	2.37 ± 0.43^{ed}	10.56 ± 0.02^{f}	0.22 ± 0.02^{a}	White
WI	2.91 ± 0.26f	9.27 ± 0.02^{e}	0.29 ± 0.01^{cb}	White

Samples with different superscripts within the same column are significantly different at P≤ 0.05. Key; BLL; Black local sesame seeds, BLI; Black improved sesame seeds, BRL; Brown local sesame seeds. BRI; Brown improved sesame seeds, WL;White local sesame seeds WI; White improved sesame seeds.

Table 2: Proximate Composition of black, brown and white colored sesame seed varieties

Sample	Moisture (%)	Protein (%).	Fibre (%)	Fat (%)	Energy (Kcals)	Carbohydrate (%)	Ash (%)
BLL	4.5 ± 0.02^{f}	21.9 ± 0.02^{b}	22.7 ± 0.02^{d}	25.9 ± 0.02^{a}	496.6 ± 0.02^{a}	20.4 ± 0.02^{f}	4.22 ± 0.01^{b}
BLI	4.27 ± 0.02^{e}	19.7 ± 0.02^{a}	31.1 ± 0.02^{f}	32.4 ± 0.02^{b}	531.3 ± 0.02^{b}	9.07 ± 0.02^{c}	3.43 ± 0.01^{a}
BRL	3.58 ± 0.02^{c}	28.4 ± 0.02^{d}	11.5 ± 0.02^{c}	38.7 ± 0.02^{d}	558.3 ± 0.02^{d}	12.7 ± 0.02^{e}	5.17 ± 0.02^{e}
BRI	3.77 ± 0.02^{d}	24.0 ± 0.02^{c}	24.0 ± 0.02^{e}	36.2 ± 0.02^{c}	547.6 ± 0.02^{c}	7.34 ± 0.02^{b}	4.52 ± 0.02^{c}
WL	3.02 ± 0.02^{b}	24.5 ± 0.02^{e}	8.23 ± 0.02^{a}	48.0 ± 0.02^{f}	609.9 ± 0.02^{f}	11.7 ± 0.02^{d}	4.57 ± 0.02^{d}
WI	2.82 ± 0.02^{a}	27.2 ± 0.02^{f}	10.1 ± 0.02^{b}	47.3 ± 0.02^{e}	603.7 ± 0.02^{e}	7.32 ± 0.02^{a}	5.37 ± 0.02^{f}

Samples with different super scripts in the same column are significantly different at P≤0.05.
Key; BLL; Black local sesame seeds, BLI; Black improved sesame seeds, BRL ;Brown local sesame seeds , BRI ;;Brown improved sesame seeds, WL ;;White local sesame seeds WI; White improved sesame seeds, Mc; Moisture content , Prt; Protein content, Cho; Carbohydrates

Table 3: Mineral compositions (mg/100gwt) of black, brown and white colored sesame seed varieties

Sample/ Mineral	**Macro-Minerals**						
	Na	**K**	**Ca**	**Mg**	**P**	**Cl**	**S**
BLL	39.0 ± 0.02^{a}	455.8 ± 0.01^{c}	233.8 ± 0.02^{d}	104.4 ± 0.02^{d}	129.3 ± 0.03^{a}	0.04 ± 0.01^{c}	0.02 ± 0.01^{cd}
BLI	46.0 ± 0.02^{c}	323.4 ± 0.01^{a}	189.5 ± 0.02^{b}	74.3 ± 0.02^{a}	155.3 ± 0.01^{c}	0.45 ± 0.02^{f}	0.02 ± 0.01^{dc}
BRL	63.0 ± 2.62^{d}	611.7 ± 0.02^{f}	166.7 ± 0.01^{a}	91.3 ± 0.02^{c}	225.1 ± 0.01^{d}	0.02 ± .02^{b}	0.01 ± 000^{ba}
BRI	42.1 ± 0.01^{b}	386.9 ± 0.01^{b}	210.9 ± 0.01^{c}	85.3 ± 0.01^{b}	133.9 ± 0.05^{b}	0.02 ± .01^{a}	0.00 ± 0.00^{abc}
WL	74.4 ± 0.01^{e}	505.0 ± 0.01^{d}	556.9 ± 0.015^{f}	132.1 ± 0.01^{f}	428.4 ± 0.01^{e}	0.08 ± 0.01^{e}	0.05 ± 0.01^{ed}
WI	87.9 ± 0.02^{f}	511.5 ± 0.02^{e}	511.8 ± 0.01^{e}	125.9 ± 0.01^{e}	433.8 ± 0.01^{f}	0.07 ± 0.01^{d}	0.05 ± 0.02^{de}
	Micro **Mine Micro-Minerals**						
	Mn	Cu	I	Zn	Fe	Fl	N
BLL	34.7 ± 0.02^{d}	34.6 ± 0.02^{d}	0.28 ± 0.02^{a}	12.22 ± 0.02^{b}	11.91 ± 0.01^{d}	0.23 ± 0.01^{ba}	0.71±.01de
BLI	22.4 ± 0.01^{c}	22.4 ± 0.01^{a}	0.34 ± 0.01^{b}	16.33 ± 0.02^{cd}	9.15 ± 0.01^{ab}	0.25 ± 0.01^{c}	0.68±.01^{bcb}
BRL	18.6 ± 0.01^{a}	18.5 ± 0.01^{c}	0.34 ± 0.01^{c}	16.33 ± 0.02^{dc}	9.15 ± 0.01^{ba}	0.25 ± 0.01^{d}	0.68±.01^{c}
BRI	21.3 ± 0.01^{b}	21.3 ± 0.01^{b}	0.57 ± 0.02^{d}	9.05 ± 0.01^{a}	10.44 ± 0.02^{c}	0.22 ± 0.01^{ab}	0.58±.02^{a}
	77.2 ± 0.01^{f}	77.23 ± 0.01^{e}	0.82 ± 0.02^{e}	17.45 ± 0.02^{e}	14.65 ± 0.02^{e}	0.25 ± 0.01^{edc}	0.75 ± 0.01^{f}
WI	51.2 ± 0.02^{e}	51.23 ± 0.02^{f}	0.83 ± 0.02^{f}	21.22 ± 0.02^{f}	18.45 ± 0.02^{f}	0.32 ± 0.01^{f}	0.71 ± 0.01^{ed}

Samples with different super scripts in the same column are significantly different at P≤0.05. Key; BLL; Black local sesame seeds, BLI; Black improved sesame seeds, BRL;Brown local sesame seeds. BRI; Brown improved sesame seeds, WL;White local sesame seeds WI; White improved sesame seeds.

Table 4: Phytochemical compositions of black, brown and white colored sesame seeds

Sample/ Phytochemical	Oxalates (%)	Phytates (%)	Tannins (%)	Phenols (μ/g)	Flavanoids (μ/g)
BLL	0.7 7± 0.09^{def}	0.14 ± 0.01^{cd}	8.7 ± 0.10^{ef}	1.48 ± 0.10^{e}	2.46 ± 0.01^{ef}
BLI	0.43 ± 0.02^{abc}	0.27 ± 0.13^{f}	9.07 ± 0.06^{ef}	1.10 ± 0.10^{d}	2.01 ± 0.01^{a}
BRL	0.62 ± 0.21^{cba}	0.11 ± 0.01^{a}	8.10 ± 0.95^{cd}	1.12 ± 0.10^{ab}	2.23 ± 0.02^{bc}
BRI	0.50 ± 0.18^{abc}	0.19 ± 0.01^{d}	7.8 ± 0.87^{b}	1.11 ± 0.02^{bc}	2.25 ± 0.02^{bc}
WL	0.96 ± 0.01^{efd}	0.12 ± 0.01^{b}	8.37 ± 0.38^{d}	1.69 ± 0.01^{b}	2.45 ± 0.01^{ef}
WI	0.88 ± 0.01^{edf}	0.13 ± 0.01^{ed}	7.80 ± 0.10^{a}	1.43 ± 0.10^{f}	2.42 ± 0.01^{d}

Samples with different super scripts in the same column are significantly different at P≤0.05.
Key; BLL; Black local sesame seeds, BLI; Black improved sesame seeds,BRL;Brown local sesame seeds , BRI ;;Brown improved sesame seeds, WL ;;White local sesame seeds, WI; White improved sesame seeds.

Table 5: Functional properties of black, brown and white colored sesame seed varieties

Sample/ Parameter	B D (g/ml)	WAC (ml/g)	OAC (ml/g)	EMC (%)	FC (%)	FS (%)
BLL	0.54 ± 0.02^{b}	1.35 ± 0.05^{a}	1.56 ± 0.20^{e}	50.0 ± 0.20a	4.00 ± 2.00^{a}	25.0 ± 2.00^{a}
BLI	0.47 ± 0.02^{a}	1.67 ± 0.31^{a}	1.56 ± 0.20^{e}	49.2 ± 0.03a	10.0 ± 2.00^{c}	60.0 ± 2.00^{b}
BRL	0.57 ± 0.02^{b}	1.30 ± 0.30^{a}	1.20 ± 0.05^{c}	49.4 ± 1.22a	8.00 ± 1.00^{b}	45.0 ± 3.00^{c}
BRI	0.53 ± 0.03^{b}	1.60 ± 0.20^{a}	1.38 ± 0.20^{d}	49.6 ± 0.57a	8.00 ± 2.00^{b}	50.0 ± 1.00^{c}
WL	0.81 ± 0.01^{c}	1.6 ± 0.05^{a}	0.83 ± 0.20^{a}	49.9 ± 0.57a	12.0 ± 2.00^{b}	50.3 ± 1.53^{c}
WI	0.93 ± 0.04^{d}	1.2 ± 0.01^{a}	0.92 ± 0.20^{b}	49.6 ± 0.57a	8.00 ± 1.00^{b}	50.0 ± 1.00^{d}

Samples with different superscripts Within the same column are significantly different at P≤ 0.05 / Key; BLL; Black local sesame seeds, BLI; Black improved sesame seeds, BRL ;Brown local sesame seeds , BRI ;;Brown improved sesame seeds, WL ;;White local sesame seeds, WI; White improved sesame seeds, BD; Bulk density, WAC; Water absorption capacity, OAC; Oil absorption capacity, EMC; Emulsion capacity.

IV. Conclusions

This study evaluated the chemical composition, functional and phytochemical properties of black, brown and white varieties of Nigerian sesame seeds. The result showed that differences in the chemical and nutritional composition of the seeds were largely depended on the varieties. Even though the functional properties of all the sesame varieties showed not much differences, the phytochemical and the mineral content were different with the varieties of the seeds. This study is therefore in assisting processors of sesame seeds to design appropriate formulation strategies for the resulting products of sesame varieties.

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