Nutritional Analysis of the Three Commonly Consumed Varieties of Benni Seeds (Sesame Seeds) in Plateau State, Nigeria

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ABSTRACT

This study analyzed the nutritional composition of three varieties of Benni seeds (white, large black, and small black) from Plateau State, Nigeria. The proximate analysis of the samples was determined using methods described by the Association of Analytical Chemists (2018). Proximate analysis revealed no significant difference ($p \leq 0.05$) in ash, crude fibre, crude protein, lipids, and moisture content among the varieties, but a significant difference ($p \leq 0.05$) in carbohydrate content. White Benni seeds had the highest crude fibre (32.37±0.04), large black seeds the highest carbohydrate (3.21±0.02) and lipid (34.02±0.02), and small black seeds the highest moisture (5.40±0.03), crude protein (31.10±0.23), and ash (7.80±0.02). Mineral analysis showed calcium and phosphorus in all samples, with significant variation ($p \leq 0.05$) in calcium, but not phosphorus. All three varieties were low in mineral content.

Keywords: Nutritional Composition, Benni seeds, Proximate composition and Mineral analysis.

INTRODUCTION

Benni seeds, generally referred to as Sesame seeds, are nutrient-rich seeds that have been consumed for centuries in various parts of the world (Imran *et al.*, 2020), including Plateau State, Nigeria. These small, oval-shaped seeds come in different colours, such as white, black, and brown, and are widely used in both culinary and medicinal purposes (Tadayyon, 2013). They are known for their high oil content and are a rich source of protein, fibre, vitamins, and minerals (Sharma *et al.*, 2021).

In Plateau State, the three commonly consumed varieties of benni seeds are white, black (large), and sunflecks (small black). While these varieties share the same clades and order in the taxonomical ranking, they differ in family, genus, and species type — the white and large black varieties have *Sesamum indicum* as their generic and specific names while the small black variety, *Guizotia scarba*. Despite this diversity, benni seeds remain an essential component in the local diet, adding a unique nutty flavour to soups, stews, and sauces. Beyond their culinary significance, these seeds are also valued for their medicinal properties, with traditional healers utilizing them for centuries to address ailments like digestive disorders, respiratory issues, and skin problems (Abbas *et al.*, 2022).

Benni seeds have a high nutrient content, including fat, protein, minerals, vitamins, and dietary fibre. The oil extracted from benni seeds is rich in unsaturated fatty acids, fat-soluble vitamins, and amino acids. Benni seeds are known as an "all-purpose nutrient bank" and the "crown of eight grains" (Haixia and Lu, 2015).

The protein in benni seeds is a complete protein with essential amino acids that are similar to those found in the human body (Morris *et al.*, 2021). Benni seeds contain a variety of proteins; including globulin, clear protein, alcoholic protein, and glutenin, with globulin having the highest content (Cui *et al.*, 2021; Fuji *et al.*, 2018).

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Studies have shown that benni seed protein isolate has a high in vitro protein digestibility, making it a suitable supplement for protein-deficient populations, particularly in developing countries (Dossa *et al.*, 2017). The colour of the benni seed coat affects its protein content, with black benni seeds having higher protein content than white benni seeds (Cui *et al.*, 2021; Vangaveti *et al.*, 2016). Nineteen essential amino acids have been identified in benni seeds, including alanine, arginine, cysteine, glutamic acid, lysine, phenylalanine, and others (Wang *et al.*, 2020), which are essential for the growth and repair of body tissues (Manasa *et al.*, 2020).

Benni seeds have high oil content, earning them the title of the "Queen of Oil" (Hu *et al.*, 2007). Benni seed oil contains predominantly unsaturated fatty acids, including linoleic acid and linolenic acid, which are essential fatty acids that must be obtained through diet (Dar and Arumugam, 2013). Excessive consumption of benni seeds can lead to weight gain and potential health risks such as gastrointestinal discomfort, endocrine disruption, increased risk of cardiovascular disease, and hypotension (Dalibalta *et al.*, 2020; Phang *et al.*, 2009; Nyantika *et al.*, 2016). The oil and protein content of benni seeds have a negative correlation and are influenced by genotype and environment (Li *et al.*, 2014). Twelve unsaturated fatty acids have been identified in benni seeds, including oleic acid, linoleic acid, palmitic acid, stearic acid, and others (Wu *et al.*, 2017). These fatty acids contribute positively to cardiovascular health by reducing levels of bad cholesterol and serving as a reliable source of energy (Anilakumar *et al.*, 2010).

Benni seeds contain various vitamins, with vitamin E being the most abundant (Mili *et al.*, 2021). Vitamin E, specifically γ-tocopherol, has strong antioxidant activity in benni seeds (El Hanafi *et al.*, 2023), which safeguards cells from damage, boosts the immune system, and supports skin and eye health (Namiki, 1995). Twelve vitamins have been reported in benni seeds, including vitamin A, thiamine, riboflavin, niacin, folic acid, ascorbic acid, and various forms of tocopherols and tocotrienols. These vitamins are essential for energy metabolism, brain health, and maintaining healthy skin (Hegde, 2012).

Benni seed hull, a by-product of oil extraction, mainly consists of carbohydrate polymers such as hemicelluloses, cellulose, and pectic polysaccharides (Liu *et al.*, 2021), and these facilitate a gradual release of energy, contributing to the maintenance of stable blood sugar levels (Wankhede and Tharanathan, 1976). Benni seeds contain seven carbohydrates, including glucose, galactose, fructose, and various forms of complex carbohydrates (Sun *et al.*, 2022).

Benni seeds offer a rich array of minerals, including calcium, vital for maintaining robust bones and teeth, as well as ensuring proper muscle and nerve function. Iron, present in these seeds, is crucial for the production of red blood cells and the prevention of anaemia. Benni seeds also provide a significant amount of magnesium, supporting bone health, muscle function, nerve transmission, and blood pressure regulation. Additionally, these seeds serve as a source of zinc, playing a crucial role in immune function, wound healing, and cell growth (Alyemeni *et al.*, 2011).

In Plateau State, benni seeds have long been a staple ingredient in traditional dishes. One of the most popular traditional recipes involving benni seeds is called "tuwo", which is a thick porridge made from grains such as millet, guinea corn, or maize. Benni seeds are often ground into a fine powder and added to the porridge, enhancing its flavor and nutritional content. Tuwo served with stew or soup is a common meal in many households in Plateau State. "Ámwam" (Tarok) is another traditional dish that incorporates benni seeds, specifically the white variety. This dish is a type of porridge that is prepared with dried fish or meat and a variety of vegetables. To enhance the flavor and aroma of the porridge, the benni seeds are roasted and ground before being added. Moreover, the white benni seed holds a significant dietary role in the making of candies, and the creation of savoury soups that feature fresh vegetables such as spinach and moringa. Furthermore, the oil extracted from the white benni seeds can be used for frying yams and in the preparation of sauces. The large black benni seeds not only enhance the taste of meat and yam dishes, but they also contribute to their appetizing appearance. This cooking tradition is prevalent among the Berom people of Plateau State. Additionally, the indigenous society on the Plateau has adopted the practice of using sauced benni seeds to complement the local soybean cake known as "awàra" (Hausa). Furthermore, the small black benni seed has gained significant popularity among the Ron-Kulere and Challa people of Bokkos LGA in Plateau, as well as among other Plateau locals, due to its ability to add a delightful flavor to the traditional "Bubal" meal, which consists of cooked beans mixed with palm oil.

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Benni seeds are not only used as a main ingredient but also as a condiment or spice in Plateau State's cuisine. One common condiment made from benni seeds is "yaji". Yaji is a blend of roasted benni seeds, groundnut, dried peppers, and various spices. It is typically used as a seasoning for grilled or roasted meats, adding a hint of smokiness and spiciness to the dish. Yaji is a key component of the famous Plateau State barbecue, known as "suya".

The culinary use of benni seeds extends beyond solid food and into the realm of beverages. In Plateau State, a traditional drink called "kunun aya" is made from benni seeds. The seeds are soaked in water and then blended with other ingredients such as millet, ginger, and sugar. The resulting drink is nutritious and refreshing, often enjoyed during hot summer months.

Figure 1: The White Benni Seeds

Figure 2: The Large Black Benni Seeds

Figure 3: The Small Black Benni Seeds (Sunflecks)

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MATERIALS AND METHODS

Sample Collection and Preparation

The white, large black and small black varieties of Benni seeds were sourced from farmers in Bokkos Local Government of Plateau State. A taxonomist (Joseph Jeffrey Azila) based at the Federal College of Forestry in Jos, authenticated and identified the samples within the laboratory setting. Subsequently, the seeds underwent natural drying before being ground into a powdered form and stored for further analysis.

Proximate Analysis

The proximate analysis of the three varieties of Benni seeds was conducted following the standard methods outlined by the Association of Analytical Chemists (AOAC, 2018). Moisture content was determined by heating 2.0g of each sample to a constant weight in a crucible placed in an oven maintained at 105^{o}C for 18 hours. The dry matter was used in the determination of the other parameters. Crude protein (% total nitrogen x 6.25) was determined by the Kjeldahl method, using 2.0g samples; crude fat was obtained by exhaustively extracting 2.0g of each sample in a Selecta Fat Extractor using petroleum ether (boiling point range 84°C) as the extractant. Ash was determined by the incineration of 2.0g samples placed in a muffle furnace maintained at 600°C for 5 hours. Crude fibre was obtained by digesting 1.0g of defatted sample with H_2SO_4 and NaOH and incinerating the residue in a muffle furnace maintained at 600°C for 5 hours. Each analysis was carried out in triplicate. Available carbohydrate percentage was calculated by difference (AOAC, 2018), and energy values were derived using general Atwater factors (Sally *et al.,* 1997).

Analysis of Mineral Elements

Determination of Calcium

4 ml aliquot of the digested sample was carefully pipetted and dispensed into an Eppendorf centrifuge tube. To induce precipitation of calcium, 8.5ml of 24% HCl was added to the sample. The content of the Eppendorf tube was then transferred into a beaker containing a small volume of distilled water and placed on a hot plate, where it was heated for 5-10 minutes to expedite precipitation. Subsequently, the sample underwent centrifugation at 3000 for 5 minutes, causing the calcium oxalate (ppt) to sediment at the bottom of the centrifuge tube. The supernatant was discarded using the invasion method. To remove excess ammonium oxalate, 3 ml of 2% NH_4OH was added, and the resulting solution underwent centrifugation once more at 3000 for 5 minutes. Finally, 2 ml of 20% H_2SO_4 was pipetted into the tube, and the resulting solution was titrated against 0.01M $KMnO_4$ (Katoch, 2022).

The volume of $KMnO_4$ utilised in the titration is directly proportional to the amount of calcium present in the particular sample under examination.

Determination of Phosphorus

19 ml of distilled water was dispensed into a sample tube, and another 20 ml was dispensed into a sample tube labelled blank. In the first sample tube, 1 ml of the digested sample was added. Both tubes received 5 ml of Molybdovanadate reagent and were left to stand at room temperature for 3-5 minutes, allowing for colour development. The intensity of the colour observed is directly proportional to the amount of phosphorus present in the sample. Subsequently, the absorbance was read at 470, with the blank used to zero the spectrophotometer (Galyean, 1989; Oloruntola, 2021).

Statistical Analysis

Statistical analysis of the data was done with the Statistical Package for Social Sciences (SPSS), for Windows version 16.0, using a one-way analysis of variance (ANOVA) followed by post hoc Tukey's HSD (honestly significant difference) test. Significant difference was accepted at $p < 0.05$ and results were expressed as Mean ± Standard Deviation.

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RESULTS AND DISCUSSION

Results

The proximate composition of the three varieties of Benni seeds is shown in Table 1 below. Lipids emerged as the dominant component across all tested seeds, with crude fibre, crude protein, ash, moisture content, and carbohydrates following closely behind. Among the varieties, Small Black Benni seeds exhibit the highest concentrations of most nutrients analyzed.

The result of mineral analysis of three varieties of Benni seeds is shown in Table 2. The seeds exhibited moderate levels of calcium and Phosphorus, with White Benni seeds showing slightly higher levels of phosphorus compared to Large Black and Small Black Benni seeds, which had lower phosphorus content.

Table 1: Proximate Composition of the Three Commonly Consumed Varieties of Benni seed

Samples	Moisture Content (%)	Crude Protein (%)	Crude Fibre (%)	Lipids (%)	Ash (%)	NFE (%)	Energy (Kcal/g)
Benni seeds (White)	3.58±0.03[a]	27.06±0.33[b]	32.37±0.04[c]	32.02±0.08[d]	4.95±0.09[e]	0.02±0.50[f]	396.50
Benni seeds (Large Black)	4.80±0.02[a]	23.21±0.02[b]	31.04±0.01[c]	34.02±0.02[d]	3.70±0.07[e]	3.21±0.02[f]	412.04
Benni seeds (Small Black)	5.40±0.03[a]	31.10±0.23[b]	20.05±0.02[c]	33.00±0.46[d]	7.80±0.02[e]	2.65±0.20[b]	432.00

The values represent means ± standard deviation of three determinations. Values in the same column with differing superscripts are significantly distinct from each other (P≤ 0.05). NFE stands for Nitrogen-Free Extract, representing soluble carbohydrates.

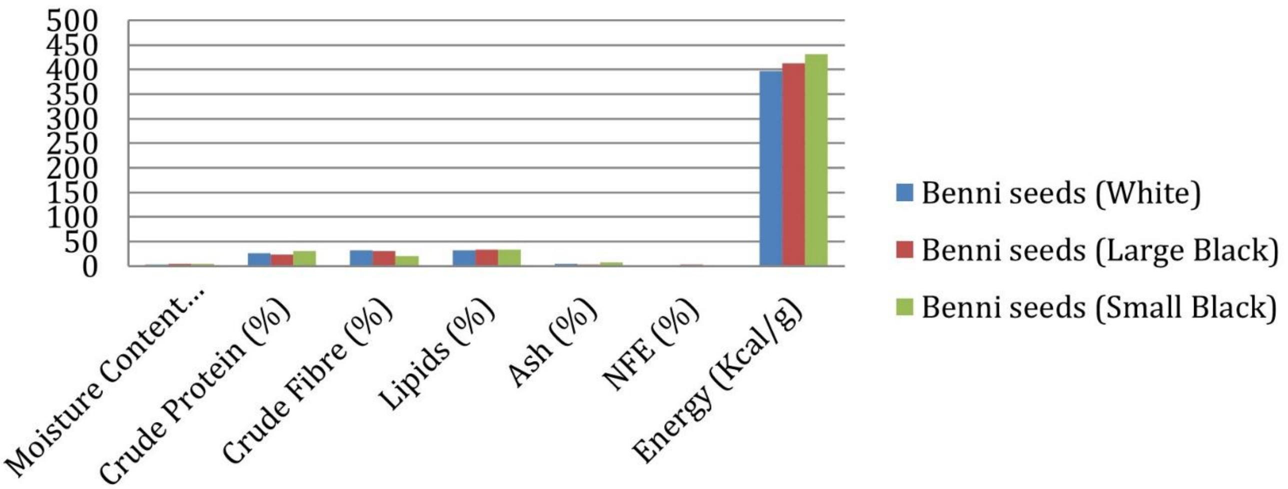

Figure 4: Distribution of Proximate Composition of the Three Commonly Consumed Varieties of Benni seed

Table 2: Result for the Mineral Elements Analysis of the Three Commonly Consumed Varieties of Benni seeds

Mineral elements	Benni seeds (White)	Benni seeds (Large Black)	Benni seeds (Small Black)
Calcium (Ca) ppm	0.75±0.01[a]	0.50±0.16[a]	0.50±0.02[c]
Phosphorus (P) ppm	0.16±0.03[b]	0.08±0.03[b]	0.09±0.01[b]

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The values represent means ± standard deviation of three determinations. Values in the same row with differing superscripts are significantly distinct from each other (P≤ 0.05). "PPM" stands for parts per million.

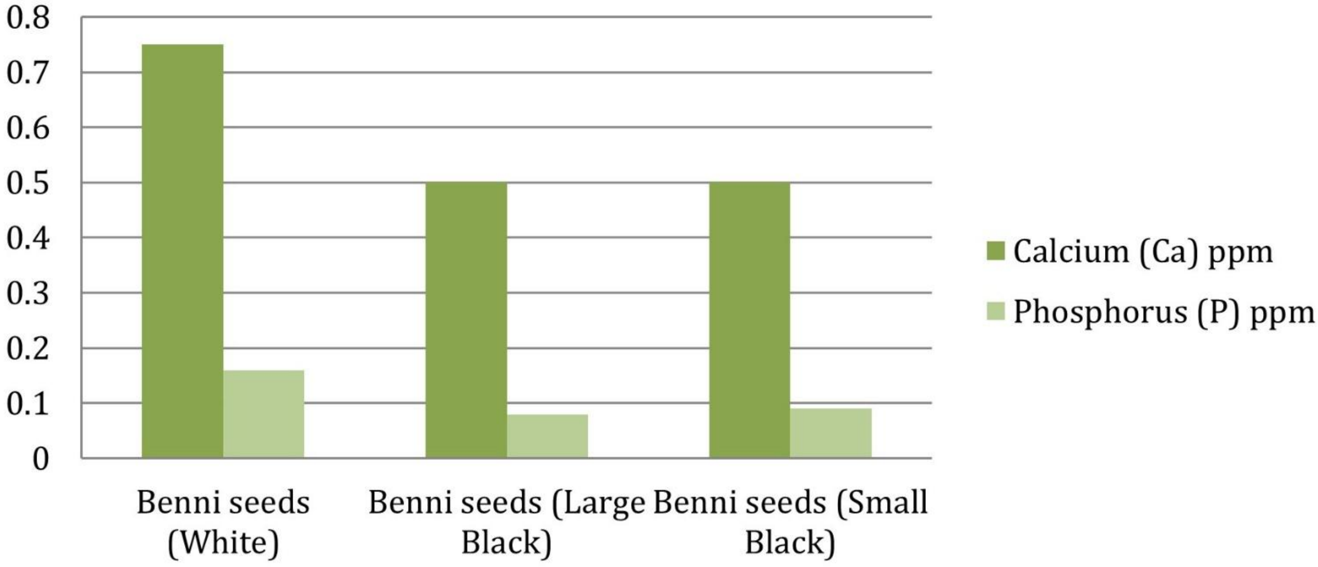

Figure 5: Distribution of Mineral Element Analysis of the Three Commonly Consumed Varieties of Benni seed

Discussion

Proximate Analysis

The moisture content of white, large black and small black Benni seeds exhibits no significant difference ($p < 0.05$) among them. The mean moisture content values for these three varieties of Benni seeds are low and consistent with the findings of Dashak and Fali (1993), as well as similar to moisture content levels reported for various other food crops (Godin and Spensley, 1971; Rudrapatnam *et al.*, 1975; Oyenuga, 1978; Shambe and Dashak, 1995; Temple and Bassa, 1991). This suggests a prolonged shelf life, making Benni seeds a suitable food storage option in regions where food preservation remains a challenge. Reduced moisture content minimizes microbial growth and deterioration (Cutter, 2002; Kong and Singh, 2016), thereby ensuring food security, particularly in areas prone to post-harvest losses.

In terms of crude protein content, the small black Benni seeds exhibited the highest mean value at 31.10±0.23, followed by white Benni seeds with a mean crude protein value of 27.06±0.33, and large black Benni seeds with a mean crude protein value of 23.21±0.02. However, the mean protein difference among all samples shows no significant variation ($p < 0.05$). The crude protein values obtained for all three samples in this study are moderately higher than the ranges reported in the literature by Godin and Spensley (1971), Ensminger and Ensminga (1994), Bamigboye *et al.* (2010), Dashak and Fali (1993), as well as other plant fruits, seeds, and nuts (Tressler *et al.*, 1980; Nahar *et al.*, 1990; Hernández-Pérez *et al.*, 1994). The significant crude protein value observed in small black Benni seeds (31.10±0.23) is slightly higher compared to the findings of Dashak *et al.* (2002) (17.33±0.18%). Although both samples were obtained from the same geographical location, differences may arise from variations in topography and soil texture. Given that proteins are crucial for muscle repair, enzyme synthesis, and overall metabolic functions, the high protein content of Benni seeds makes them a valuable dietary component, particularly for populations in Plateau State where protein deficiency remains a public health concern. Promoting Benni seed consumption could support protein intake diversification, reducing reliance on animal sources that may be less accessible or affordable.

The lipid content analysis revealed no significant difference ($p < 0.05$) among white, large black and small black Benni seeds. Large black Benni seeds exhibited the highest lipid content at 31.04±0.01%, followed by small black Benni seeds at 33.00±0.46%, and then white Benni seeds at 32.02±0.08%. This finding aligned with the observations of Ensminger and Ensminger (1994). Lipids are critical for energy supply, hormone synthesis, and the absorption of fat-soluble vitamins. Additionally, Benni seed oil has been shown to enhance pyrethroid and organophosphorus pesticides (Ruiquan, 1995) and exhibit antihypertensive properties (Takayoshi *et al.*, 1995). Given the increasing prevalence of cardiovascular diseases, promoting the use of Benni seed oil as a functional food ingredient could provide health benefits beyond nutrition.

The crude fibre analysis revealed no significant difference ($p < 0.05$) in the crude fibre content among white, large black and small black Benni seeds. Notably, white Benni seeds exhibited the highest significant crude fibre value (32.37±0.04%), substantially surpassing the findings of Dashak and Fali (1993) (14.2±0.1%). High fibre content has been associated with various benefits, including prevention of constipation and diverticulosis, removal of toxic materials from the body by binding to them, and promotion of easy and bulky stooling (McDougall *et al.*, 1996; Jansen, 1980). Additionally, the high fibre content of Benni seeds supports their role in dietary interventions aimed at managing conditions such as diabetes and obesity (Anderson and Ward, 1979; A Larrauri *et al.*, 1996), which are increasingly prevalent in Nigeria. Incorporating Benni seeds into local diets could enhance dietary fibre intake, promoting long-term gastrointestinal and metabolic health.

Regarding ash content, an indicator of mineral composition, no significant differences ($p < 0.05$) were observed among the varieties. The high ash content aligned with previous studies (Dashak and Fali, 1993; Dashak *et al.*, 2002), indicating the presence of essential minerals critical for various physiological functions.

The mean carbohydrate content (Nitrogen-Free Extract) of the three Benni seed varieties fell within the range of 0.02% to 3.21%, significantly lower than the range reported by Dashak and Fali (1993) and Dashak *et al.* (2002). Carbohydrates constitute the lowest portion of all proximate constituents in Benni seeds and exhibit a significant difference between large black and small black Benni seeds ($p < 0.05$), whereas no significant difference was observed between white Benni seeds and either large black or small black Benni seeds ($p < 0.05$). Given the low carbohydrate content of Benni seeds, their consumption should be complemented with carbohydrate-rich foods to meet energy requirements, particularly for physically active individuals and vulnerable groups such as children and pregnant women. This is because carbohydrates play a crucial role in providing the body with essential energy, serving as a necessary nutrient for a balanced diet (Emebu and Anyika, 2011) and supplying energy to vital cells such as those in the brain, muscles, and blood (Ejelonu *et al.*, 2011).

Mineral Elements Analysis

The calcium content analysis of the three Benni seed varieties revealed very low levels, with white Benni seeds exhibiting the highest calcium content (0.75±0.01 ppm), and large black and small black Benni seeds displaying identical calcium content (0.50±0.16 ppm) and (0.50±0.02 ppm), respectively.). Significant differences ($p < 0.05$) were noted between large black and small black Benni seeds but not with white Benni seeds. These findings aligned closely with the reported values of Dashak and Fali (1993). While the calcium levels are relatively low compared to recommended dietary intakes, they still contribute to skeletal health and blood clotting (Mudambi, 2001). Given the prevalence of calcium deficiency-related conditions such as osteoporosis, encouraging Benni seed consumption alongside calcium-rich foods could improve overall dietary calcium intake.

Phosphorus content was also low, with white Benni seeds having the highest phosphorus content (0.16±0.03 ppm), followed by small black (0.09±0.01 ppm) and large black Benni seeds (0.08±0.03 ppm). There was no significant difference ($p < 0.05$) in the phosphorus content among all three Benni seed samples. These values were significantly lower than previous reports (Dashak and Fali, 1993; Dashak *et al.*, 2002), which may be attributed to soil composition and agronomic practices (Zhai *et al.*, 1990). Phosphorus is essential for bone formation, energy metabolism, and cellular function, making even low amounts beneficial to human health (Penido and Alon, 2012).

The phosphorus content analysis of the three Benni seed varieties revealed very low levels, with white Benni seeds having the highest phosphorus content (0.16±0.03 ppm), followed by small black Benni seeds (0.09±0.01 ppm), and then large black Benni seeds (0.08±0.03 ppm). These findings were significantly lower compared to the reported values of Dashak and Fali (1993) and Dashak *et al.* (2002). However, there was no significant difference ($p < 0.05$) in the phosphorus content among all three Benni seed samples.

The differences in mineral element values could stem from various factors including geographical location and agronomic practices. Specifically, the calcium and phosphorus content of large black Benni seeds and small black Benni seeds (0.50±0.16 and 0.08±0.03, and 0.50±0.02 and 0.09±0.01, respectively) were notably lower compared to white Benni seeds (0.75±0.01 and 0.16±0.03). Similar variations in the mineral composition of foods have been documented by Zhai *et al.* (1990), and the values closely resemble those reported for barley by Shambe and Dashak (1995) and Muralidharudu and Mev (1990). Generally, all the samples exhibited lower mineral values compared to those reported by Dashak *et al.* (2002).

Minerals like calcium and phosphorus are crucial for maintaining optimal bodily functions and are therefore essential from a nutritional standpoint. Deficiencies in these minerals often result in specific syndromes. They serve vital roles such as contributing to the development of the body's skeletal system and facilitating processes like blood clotting, where calcium acts as a critical factor (Mudambi, 2001).

Study Limitations and Future Research

Despite the valuable insights gained from this study, certain limitations must be acknowledged. First, variations in mineral composition may be influenced by environmental factors such as soil type, climatic conditions, and agricultural practices, which were not extensively analyzed. Future research should explore these factors to determine their impact on nutrient variability. Additionally, the study did not assess the bioavailability of the nutrients, which is crucial in understanding their actual contribution to dietary intake. Further studies should incorporate bioavailability assessments using in vivo or in vitro models. Lastly, expanding the study to include other processing methods, such as roasting or fermentation, would provide insights into how different treatments affect the nutritional quality of Benni seeds.

CONCLUSION

The proximate analysis indicated that small black Benni seeds (*G. scarba*) had the highest percentage of most nutrients tested, followed by large black Benni seeds (*S. indicum*), and then white Benni seeds (*S. indicum*). Although all three varieties contained essential minerals like calcium and phosphorus, the quantities of these mineral elements were relatively low. Nonetheless, Benni seeds exhibit substantial nutritional and medicinal properties. With their abundance of macro and micronutrients, Benni seeds can serve as a significant staple food, potentially addressing and mitigating hunger and food insecurity in Nigeria.

RECOMMENDATIONS

The findings of this study have significant implications for policy and local agricultural practices. Given the high protein and lipid content of Benni seeds, promoting their cultivation and consumption could enhance food security and nutritional status in Plateau State. Agricultural policies should focus on improving Benni seed production through better farming techniques, improved seed varieties, and soil fertility management. Additionally, food processing industries could explore value-added products such as Benni seed-based protein supplements, edible oils, and fibre-rich snacks to enhance their utilization and market value. Public health campaigns should also emphasize the health benefits of Benni seeds, particularly for protein-deficient populations and individuals at risk of cardiovascular diseases.

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