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Comparative Study of the Nutritional and Functional Properties of Flours from Three Varieties of Beans (*Phaseolus vulgaris*) from the Korhogo Market

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Abstract

The bean, *Phaseolus vulgaricus* L., is a legume that is still not among the most widely consumed plant species in Côte d'Ivoire. The aim of this study is to compare the nutritional and functional potential of flours from three bean varieties with a view to promoting their use. The biochemical, antioxidant, and the functional properties parameters were analyzed using standard methods. White bean flours had higher ash, protein, fiber, lipid, potassium, magnesium, calcium, zinc, polyphenol, and swelling power contents than red and black bean flours, with contents ranging from 3.4 to 5.2%; 17.89 to 32.58%; 14.5 to 32%; 1.2 to 1.4%; 12,780 to 19,350 mg/kg; 1793 to 2670 mg/kg; 719.70 to 1000 mg/kg; 43.10 to 47.20 mg/kg; 151.08 EAG/100g to 234.34 EAG/100g and 206.91% to 650.42%. Red bean flour had the highest iron and flavonoid content and greater water and oil absorption capacity compared to black and white bean flours, whose values ranged from 172 to 336.30 mg/kg; 46.58 EQ/100g to 56.33 EQ/100g; 176.58% to 318.86% and 81.65% to 100.95%. Black bean flour had the highest carbohydrate content compared to black and white bean flours, with values ranging from 19.63% to 51.16%. The flours from the three bean varieties studied are an important nutritional and functional source that could be exploited.

Keywords

Bean, Legume, Nutritional and Functional Potential, Valorization

1. Introduction

Among the diets recommended in the context of food security, legumes are an important lever in the quest for a balanced diet and nutrition for consumers. In Africa and Latin America, dry beans (*Phaseolus vulgaris* L.) are one of the most important and commonly consumed food legumes [1] because they are an essential food for rural populations. According to [2], dry bean production in East Africa is estimated at 4.8 million tons, 1.22 million tons in Central Africa, 0.78 million tons in West Africa, and 0.68 million tons in Southern Africa. Nutritionally, dry beans are rich in protein. They contain significant amounts of essential amino acids such as leucine, lysine, phenylalanine, isoleucine, threonine, methionine, and tryptophan [3] [4]. Dried beans are also a good source of starch, dietary fiber, minerals, and vitamins, and are rich in bioactive compounds that promote healthy development [5] [6]. This legume is therefore recommended for populations suffering from food insecurity, in order to compensate for the lack of animal protein due to financial constraints or health concerns related to the consumption of animal protein [7]. Bean seeds, whether fresh or dried and ground into flour, can be consumed in various forms. In Côte d'Ivoire, beans are mainly grown in the north, a region where they are particularly well suited. The most commonly consumed varieties of beans are white beans, followed by red beans and finally black beans [8]. It should be noted that each variety has its own specific composition. White beans, for example, are distinguished by their high content of resistant starch, which is beneficial for intestinal health. Red and black beans are particularly rich in antioxidants, especially anthocyanins, which give them their color and help fight oxidative stress [9]. Low in carbohydrates and calories, beans are ideal for low-calorie diets. They are also a good source of soluble fiber when eaten fresh or dried, and are therefore beneficial for intestinal transit. Despite their importance in terms of food and nutrition, the value of beans remains limited due to a lack of comparative data between different varieties. This legume is still not widely used among the most commonly cultivated plant species, even though its popularization could help ensure food security for the most vulnerable populations. The objective of this study was to compare the nutritional and functional potential of flours from three varieties of beans consumed in the department of Korhogo (Côte d'Ivoire) with a view to promoting their use.

2. Materials and Methods

2.1. Biological Material

The biological material used consisted of seeds from three varieties of beans purchased from seven women at the main market in Korhogo. These seeds were purchased between September and November 2024. After purchase, the seeds from the different varieties were transported to the laboratory in clean, airtight plastic jars. The botanical identification of the bean seeds was verified by a botanist from Péléforo GON COULIBALY University in Korhogo. The bean seeds were then sorted by color and placed in clean, airtight plastic jars for subsequent analysis.

2.2. Collection and Preparation of Samples for Analysis

Once in the laboratory, the bean seeds contained in the different jars by variety (red, white, and black) were ground using a micro-grinder equipped with a 10 µm sieve. The resulting flours were packaged in plastic boxes and stored at room temperature for analysis.

2.3. Evaluation of the Nutritional Properties of Flours from Three Bean Varieties

2.3.1. Moisture Content

Moisture content was determined using the [10] method. 5 g were weighed into a pre-weighed crucible and dried at 105˚C for 24 hours until a constant weight was achieved. After drying, the crucible was removed from the oven, cooled in a desiccator, and weighed. Moisture content was calculated using the formula:

$$Moisture(\%) = (m1 - m2) \times 100/me \tag{1}$$

where, $m1$: Mass of the crucible + sample before drying; $m2$: Mass of the crucible + sample after drying; me: mass of the dried powdered samples.

2.3.2. Ash

Ash content was determined using the method [10]. 5 g of dried powdered samples were weighed into a pre-weighed crucible and incinerated in a muffle furnace at 550˚C for 12 hours. After incineration, the crucible containing the ash was cooled in a desiccator and weighed. Ash content was calculated as follows:

$$Ash(\%) = (m1 - m0) \times 100/me \tag{2}$$

where, $m0$: Mass of the crucible; $m1$: Mass of the crucible + Ash; me: Mass of the dried powdered samples.

2.3.3. Proteins

Proteins content was determined using the Kjeldahl method [10]. 1 g of dried powdered samples was digested in 20 mL of concentrated sulfuric acid at 400˚C for two hours with a mineralization catalyst (potassium sulfate + selenium). After digestion, the digest was diluted to 100 mL with distilled water. A 10 mL aliquot was mixed with 10 mL of 40% NaOH, and the mixture was distilled. Distillate was collected in 20 mL of 4% boric acid containing a mixed indicator (methyl red + bromocresol green) and titrated with 0.1 N sulfuric acid. Protein content was calculated as follows:

$$Proteins(\%) = (V1 - V0) \times 14 \times N \times 6.25/me \tag{3}$$

where, $V1$: Volume of sulfuric acid for the sample; $V0$: Volume of sulfuric acid for the blank; N: Normality of sulfuric acid; me: Mass of the sample.

2.3.4. Fibres Content

For crude fibers, [11] method was used. 2 g of bean seed flour were weighed into separate 250 mL round-bottom flasks, and 50 mL of 0.25 M sulfuric acid solution was added. The mixture obtained was boiled under reflux for 30 min. Thereafter, 50 mL of 0.3 M sodium hydroxide solution was added and the mixture was boiled again under reflux for 30 min and filtered through Whatman paper. The insoluble residue was then incinerated, and weighed for the determination of crude fibers content.

$$Fibers(\%) = (m1 - m2) \times 100/2 \quad (4)$$

2.3.5. Lipids Content

Lipids content was determined using the [12] Soxhlet extraction method. 10 grams of bean seed flour were weighed into a cellulose extraction cartridge, sealed with cotton, and placed in the Soxhlet extractor with 300 mL of hexane. Extraction was carried out under reflux for seven hours. After extraction, the hexane was evaporated using a rotary evaporator, and the pre-weighed flask containing the oil was dried at 100˚C for 20 minutes, cooled in a desiccator, and weighed lipid content was calculated as follows:

$$Lipids(\%) = (m - m0) \times 100/me \quad (5)$$

2.3.6. Carbohydrates and Energy Value

Carbohydrates content and calorific value were calculated and expressed on a dry matter basis using the following formulas [13]:

$$Carbohydrates(\%) = 100 - [Mois-ture(\%) + Lipids(\%) + Proteins(\%) + Ash(\%) + Fiber(\%)] \quad (6)$$

$$Energy(kcal/100g) = (\%proteins \times 2.44) + (\%carbohydrates \times 3.57) + (\%lipids \times 8.37) \quad (7)$$

2.3.7. Mineral Analysis

The dried powdered samples 5 g were burned to ashes in a muffle furnace (Pyrolabo, France). The ashes obtained were dissolved in 10 mL of HCL/HNO3 and trans-ferred into 100 mL flasks and the volume was made up using deionized water. The mineral composition of each sample was determined using an Agilent 7500 c induc-tively coupled argon plasma mass spectrometer ICP-MS method [14]. Calibrations were performed using external standards prepared from a 1000 ppm single stock solution made up with 2% (v/v) nitric acid.

2.3.8. Polyphenol Content

Phenolic compounds are extracted with methanol using the method of [15]. 1 gram of bean seed flour is homogenized in 10 mL of 70% (v/v) methanol. The resulting mixture is centrifuged at 1000 rpm for 10 min. The pellet is recovered in 10 mL of 70% (v/v) methanol and centrifuged again. The supernatants are collected in a 50 mL flask and made up to the mark with distilled water. The resulting solution is called the methanolic extract. 1 mL of methanolic extract is introduced into a test tube and 1 mL of Folin-ciocalteu reagent is added. The tube is left to stand for 3 min, then 1 mL of 20% (w/v) sodium carbonate solution is added. The contents of the tube are made up to 10 mL with distilled water and placed in the dark for 30 min. Optical density is read at 725 nm against a blank. A standard range established from a stock solution of gallic acid (1 mg/mL) under the same conditions as the assay is used to determine the amount of phenols in the sample.

2.3.9. Flavonoid Content

The method for determining flavonoid content is that of [16]. A volume of 0.5 mL of methanolic extract is introduced into a test tube. To the contents of the tube are successively added 0.5 mL distilled water, 0.5 mL aluminum chloride and 0.5 mL sodium nitrite. The tube is left to stand for 30 min in the dark, and the optical density (OD) is read at 415 nm against a blank. The flavonoid content of the samples was determined by means of a calibration line performed under the same conditions as the assay, using a quercetin stock solution at 0.1 mg/mL.

2.4. Evaluation of the Functional Properties of Bean Flour

2.4.1. Water Absorption Capacity and Water Solubility Index

Water absorption capacity (WAC) and water solubility index (WSI) are determined according to the method of [17] [18]. 1 g of bean seed flour ($M0$) is dispersed in 10 ml of distilled water in a centrifuge tube, and the mixture is agitated for 30 min using a shaker. After shaking, the mixture is placed in a water bath at 37˚C for 30 min, then centrifuged at 4500 rpm for 15 min. After centrifugation, the pellet obtained was weighed ($M1$) and then dried at 105˚C to obtain a constant mass ($M2$). The water absorption capacity and water solubility index are calculated by the following equations:

$$WAC = (M1 - M2)/M2 \times 100 \quad (8)$$

$$WSI = (M0 - M2)/M0 \times 100 \quad (9)$$

2.4.2. Determination of Oil Absorption Capacity

Oil absorption capacity is determined using the [19]. 1 g ($M0$) of bean seed flour is dispersed in 10 mL of refined palm oil. After stirring for 30 min, the mixture is centrifuged at 4500 rpm for 10 min and the resulting sediment is weighed ($M1$). The oil absorption capacity (OAC) is calculated using the following formula:

$$OAC = (M1 - M0)/M0 \times 100 \quad (10)$$

2.4.3. Swelling Power

Swelling capacity was determined using the method described by [17] [18], with modifications. One (1) gram (M) of bean seed flour was dispersed in 10 ml of distilled water in a centrifuge tube and then placed in a water bath at 50˚C. After stirring for 1 hour under agitation. The mixture was centrifuged at 4500 rpm for 10 min. The sediment ($M1$) and supernatant were placed in different containers, then placed in an oven at 105˚C for 24 hours for the supernatant (MS) and 48 hours for the sediment ($M2$). The supernatant was used to determine solubility (S), while the pellet was used to determine swelling power (SP) according to the following relationships:

$$SP = (M1 - M2)/M2 \times 100 \quad (11)$$

2.5. Statistical Analysis

The tests were carried out in triplicate and the statistical analysis of the data was performed using SPSS software (for Windows, Version 25). The statistical processing consisted of performing an analysis of variance with a single classification criterion (ANOVA 1): the color of the bean seeds. When significant differences were observed, at a 5% error threshold, the means were classified using the Student Newman Keuls (SNK) test. The results are presented as means followed by standard deviations, illustrated by figures (graphs) and tables.

3. Results and Discussion

3.1. Results

3.1.1. Proximate Composition of Flours from Three Bean Varieties

Table 1 shows the proximate characteristics of the flour from the seeds of three bean varieties. Analysis of the data indicates a significant difference in the values obtained for all parameters evaluated between samples at P < 5%. The moisture content of bean seed flour varied according to color. This variation ranged from 9.20 ± 0.20 to 12.10 ± 0.3%. White bean seed flour had the lowest water content 9.20% compared to black and red bean flour, with values of 10.40 ± 0.2 and 12.10 ± 0.300%, respectively. The dry matter content of bean seed flour ranged from 88 ± 0.30 to 90.40 ± 0.20%. In terms of dry matter, white bean seed flour 90.80% had the highest content, followed by black bean flour 89.60% and red bean flour 87.70%. The ash content of the different bean seed flours varied depending on the variety, ranging from 3.40 ± 0.00 to 5.20 ± 0.20%. The lowest ash content was found in the black variety 3.4% and the highest content recorded 5.20% was in the white variety. In terms of protein content, the proportions varied according to the color of the bean seeds. The highest protein content was obtained with white beans 32.58%, followed by red beans 18.50% and black beans 17.89%. There was no significant variation in lipid content between the three bean varieties studied. The values obtained ranged from 1.20 ± 0.20 to 1.40 ± 0.20% for the different samples. As for fiber content, it varied significantly, with averages ranging from 14.5 ± 0.71 to 15.7 ± 0.35 and 32 ± 0.71. The highest fiber content was observed in white bean seeds, and the lowest in red bean seeds. The carbohydrate content varied significantly depending on the bean variety, with averages ranging from 19.63 ± 0.25 to 51.16 ± 0.01%. White beans had the lowest content 19.63%, followed by red beans 49.9% and black beans 51.16%. The energy value also varied depending on the bean variety. This variation ranged from 221.35± 1,50 to 288.8 ± 0.80%. The variety with the lowest energy value 221.53 kcal was white bean flour, while the variety with the highest caloric potential 288.80 kcal was black.

Table 1. Physicochemical and biochemical composition of flours from three bean varieties studied.

	Samples		
	FGHN	**FGHR**	**FGHB**
Moisture %	10 .40 ± 0.2^{b}	12.10 ± 0.30a	9.20 ± 0.20c
Ash %	3.40 ± 0.00c	3.80 ± 0.20b	5.20 ± 0.20a

Continued

Lipids %	1.40 ± 0.20a	1.20 ± 0.20a	1.39 ± 0.30a
Proteins %	17.89 ± 0.00c	18.50 ± 0.00b	32.58 ± 0.05a
Fibres %	15.75 ± 0.35b	14.5 ± 0.71c	32 ± 0.71a
Carbohydrates %	51.16 ± 0.01a	49.9 ± 0.10b	19.63 ± 0.25c
Calorific value Kcal/100g	288.8 ± 0.80b	284.4 ± 0.01c	221.35 ± 1.50a

Averages with the same superscript letter in the same row are not significantly different at the 5% level. However, different letters in the same column are significantly different at the 5% level. FGHN: Black bean seed meal; FGHR: Red bean seed meal; FGHB: White bean seed meal.

3.1.2. Mineral Composition of Flours from Three Bean Varieties

The results of the analyses showed that the mineral content of black, red, and white bean flours varies depending on the elements measured (**Table 2**). With regard to macroelements, the magnesium content in white beans is higher (2670 ± 3.30 mg/kg) than in black and red beans (1922 ± 2.00 mg/kg) and (1793 ± 3.00 mg/kg), respectively. Calcium was also higher (1000 ± 0.30 mg/kg) in white beans than in red beans (793.8 ± 0.60 mg/kg) and black beans (719.7 ± 0.70 mg/kg). In terms of potassium, white beans had the highest content (19,350 ± 2.00 mg/kg), while black beans had the lowest content (12,780 ± 2.00 mg/kg). In terms of trace elements, white bean seed flour had the highest content (47.20 ± 1.00 mg/kg) and black bean seed flour had the lowest content (43.10 ± 0.10 mg/kg). In terms of iron content, red bean seed flour had the highest content (336.30 ± 0.30 mg/kg) and white bean seed flour had the lowest content (172 ± 1.00 mg/kg). As for manganese, white bean seed flour had the highest content 76 ± 1.00 mg/kg, followed by red bean seed flour at 36.90 ± 0.10 mg/kg and black bean seed flour at 27.60 ± 0.10 mg/kg.

Table 2. Mineral composition of flours from three bean varieties studied.

	Samples		
	FGHN	**FGHR**	**FGHB**
Mg (mg/kg)	1922 ± 2.00b	1793 ± 3.00c	2670 ± 3.30a
K (mg/kg)	12,780 ± 2.00c	13,390 ± 3.00b	19,350 ± 2.00a
Fe (mg/kg)	289.30± 0.30b	336.30 ± 0. 30a	172 ± 1.00c
Ca (mg/kg)	719.70 ± 0.70c	793.80 ± 0.60b	1000 ± 0.30a
Mn (mg/kg)	27.60 ± 0.10c	36.90 ± 0.10b	76 ± 1.00a
Zn (mg/kg)	43.10 ± 0.10c	46.80 ± 0.20b	47.20 ± 1.00a

Averages with the same superscript letter in the same row are not significantly different at the 5% level. However, different letters in the same column are significantly different at the 5% level. FGHN: Black bean seed meal; FGHR: Red bean seed meal; FGHB: White bean seed meal.

3.1.3. Determination of the Antioxidant Properties of Flours from Three Bean Varieties

Regarding the polyphenol content of the flours from the different bean seeds, the study revealed a variation ranging from 151.08 ± 1.25 EAG/100g to 234.34 ± 21.91 EAG/100g. The seed flour with the highest content was that of the white variety with 234.34 EAG/100g, and those with the lowest contents were the red varieties with 169.86 EAG/100g and black with 151.08 EAG/100g (**Figure 1(A)**). As for the flavonoid content of the flour from different bean seeds, analysis of the results showed a variation from 46.58 ± 0.91 to 56.33 ± 0.91 EQ/100g. Red bean seeds contained more flavonoids (56.33 EQ/100g) than black beans (54.20 EQ/100g) and white beans (46.58 EQ/100g) (**Figure 1(B)**).

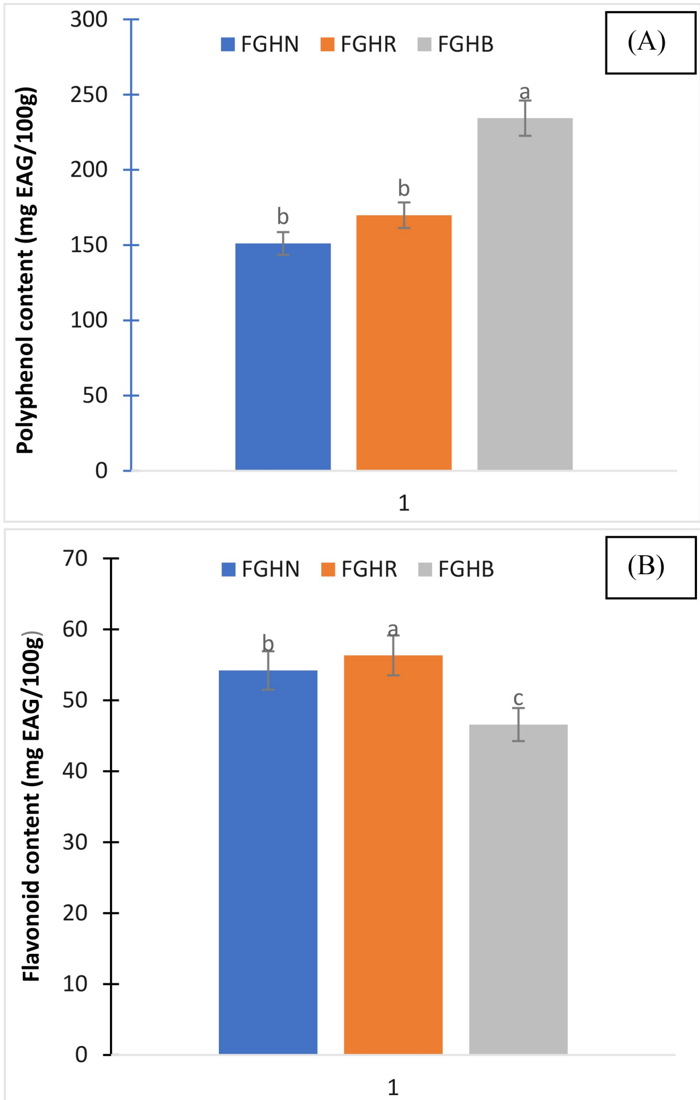

Figure 1. Polyphenols (A) and Flavonoid (B) content of flours from three bean varieties.

3.1.4. Fonctional Properties of Flours from Three Bean Varieties

The results of the analysis of the functional properties of flours from the three bean varieties are shown in **Figures 2**, **Figures 3**. Analysis of the data indicates a significant difference in the values obtained for all parameters evaluated between samples at P < 5%. For the water absorption capacity (WAC) of the different bean seed flours, Red beans had the highest WAC (318.58%) compared to white beans (181%) and black beans (176.5%) (Figure 2(A)). Regarding oil absorption capacity (OAC), the black variety had the lowest rate (81.65%), the red variety had the highest (100.95%), followed by the white variety (89.60%) (Figure 2(B)). As for the water solubility index (WSI), the white variety recorded the highest WSI (34.60%) compared to the black variety (21.40%) and red variety (19.05%) (Figure 3(A)). In terms of the swelling power (SP) of bean seed flours, the values observed were 216.81%, 217.20%, and 650.98% for black, red, and white bean flours, respectively. White bean seed flour expressed the highest PG (650.98%) compared to black and red seeds (Figure 3(B)).

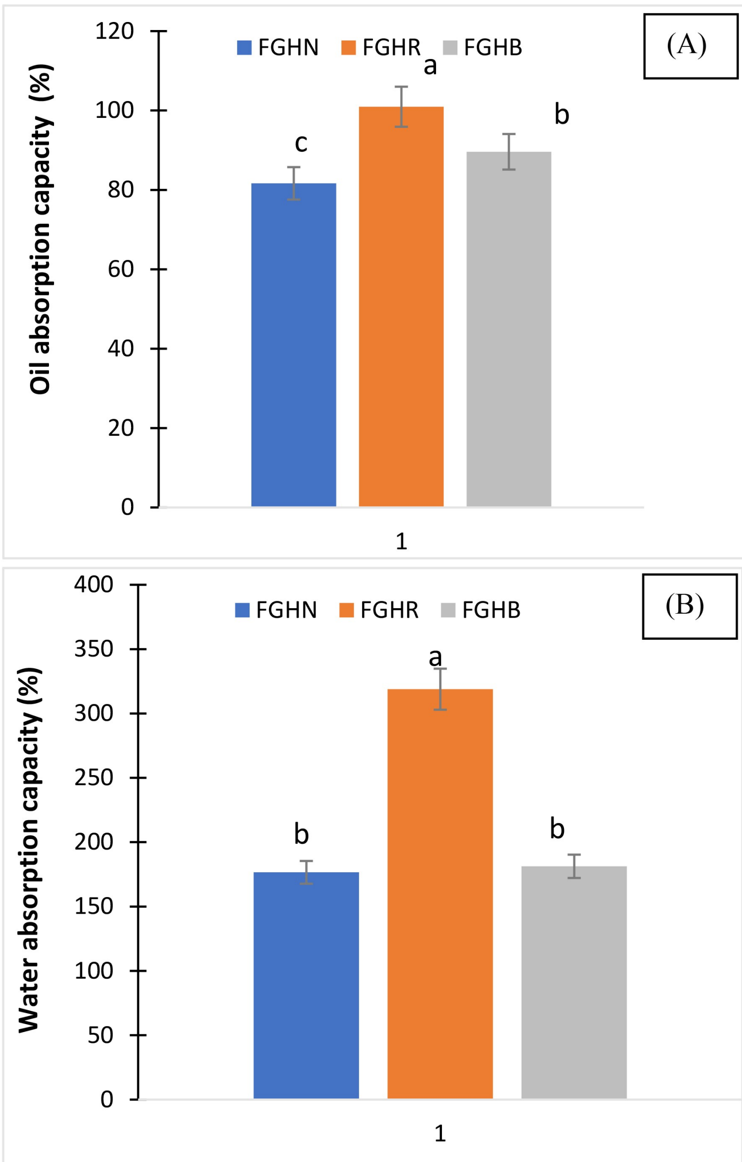

Figure 2. Oil absorption capacity (A) and water absorption capacity (B) of flours from three varieties studied.

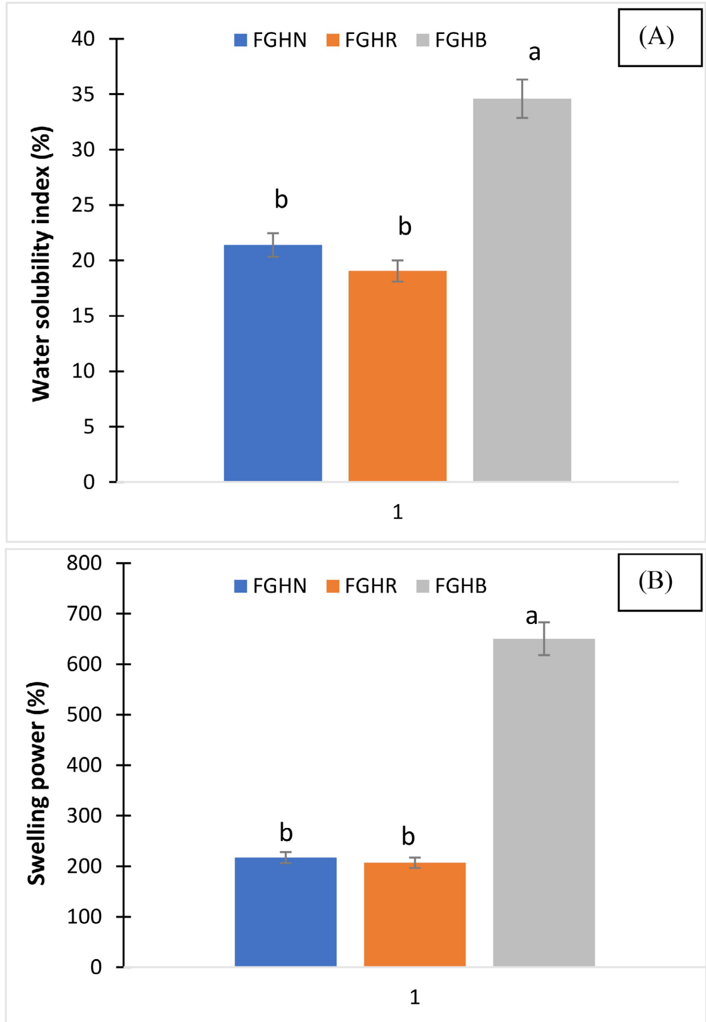

Figure 3. Water solubility index (A) and swelling index (B).

3.2. Discussion

The results of the study show that the moisture content of bean flours ranges from 9.20% to 12.10%. These values are lower than those reported [20], who obtained levels between 22.53% and 35.36% with cereal flours. The relatively low moisture content obtained with white bean seed flour would suggest a longer shelf life than that of red and black bean seeds. However, it is important to note that the three types of beans studied had relatively low moisture contents, which is favorable for the long-term storage of these seeds.

The ash content of the various bean flours studied ranges from 3.40% to 5.20%, which corroborates the values obtained by [21], which range from 3.64% to 5.23% for the control pigeon pea flour and the sprouted and roasted flours grown in the Gontougo region of Côte d'Ivoire. The highest content was observed in white bean flour, followed by red and black bean flours, which would suggest a much higher mineral content in white beans, followed by black and red beans. The ash content in the flour from the white bean seeds studied is also higher than that reported by

[22] in flours from dry red bean seeds (4.6%). This difference in ash content could be explained by the quality of the cultivated soil, which affects the mineral absorption of plants, and varietal differences [23]. These flours contain minerals such as magnesium, potassium, iron, calcium, and zinc, which are essential for the functioning of the human body.

In terms of macroelements such as Ca, although white bean seed flour had the highest content compared to red and black bean seed flours, consumption of the three bean varieties studied could contribute to the growth and maintenance of bones, muscles, and teeth [24]. Potassium is a major mineral element in cultivated soils, and its high presence in the soil would justify its high absorption by roots and its storage in seeds. The results of this study are higher than those reported by [21], who obtained potassium contents ranging from 1232 mg/100g to 1603 mg/100g for the study of different germination and roasting processes of pigeon pea flour grown in the Gontougo region of Côte d'Ivoire. The results of this study are also higher than those obtained by [25], 582.28 mg/100g for African breadfruit seeds (Treculia Africana) from Nigeria. The high potassium content in the white bean seeds studied will be of paramount importance for health because, according to [25], Potassium is required for the maintenance of osmotic balance of the body fluids, the pH of the body to prevent muscle and nerve irritability.

Regarding micronutrients, red bean seed flour is richer in iron than black and white bean seed flour. Given the high iron content in red and black bean seed flour, it could be recommended for people suffering from anemia. It is important to note that the bioavailability of iron could be influenced by the presence of antinutritional factors such as phytates and tannins, which are common in legumes. Further analysis of these compounds would therefore be necessary to assess the real nutritional potential of these flours in terms of bioavailable iron. The amount of zinc in bean flours ranges from 43.10 mg/kg for black beans to 47.20 mg/kg for white beans, showing that white beans are richer in zinc than black and red beans. The zinc contents in this study are lower than those of the local variety L120 (101.60 mg/kg) and higher than those of the local variety L10 (24.17%) reported by [26] in the nutritional study of the common bean seed collection. The differences in content observed from one location to another and from one variety to another could be explained by several factors, including the variety of beans, soil and climate conditions, cultivation practices, and methods of processing into flour. By providing sufficient amounts of these micronutrients in the human diet, it is possible to ensure normal pregnancies, as well as adequate growth and development of the child, proper functioning of the immune system, and neurobehavioral development [27].

The protein content of the different bean seeds ranged from 17.89% to 32.58%, with the highest content observed in white bean flour. The protein content of white bean seed flour is higher than that reported by [28], who obtained protein contents ranging from 24.65% to 26.15% for certain varieties of wild and edible beans in Nigeria. Given the protein content of the white bean seed flour obtained in this study, it could be used to alleviate protein-energy malnutrition problems. The bean seed flour studied, and more specifically white bean seed flour, could be used in animal feed, which would reduce the cost of modern livestock farming, which is heavily dependent on imported soybean meal and corn.

In terms of fiber content, white bean flour has the highest value (32%), but the fiber content recorded in red and black bean seed flour is not insignificant. The fiber contents obtained in this study for the three bean varieties are higher than those reported by [21], with proportions ranging from 11% to 12.29% in fresh and sprouted pigeon pea flour. This high fiber content in bean flours, particularly white bean flour, makes them an essential asset for consumer well-being, as fiber increases stool volume and facilitates bowel movements [29]. Fiber also helps control blood sugar levels.

The lipid content of bean seed flour ranged from 1.20% to 1.40%. These results are higher than those reported by [30], who obtained a lipid content of modern and local varieties of common beans (*Phaseolus vulgaris* L.) ranging from 0.33% to 1.33% and from 0.33% to 1.00%, respectively. Given the low lipid content of the flour from the bean seeds studied, they could be recommended for a low-fat diet. These results also show that bean seeds are not sources of lipids.

The carbohydrate content obtained at the end of this study ranged from 19.63% to 51.16%, with black beans having the highest content. Black beans would be an excellent choice for the formulation of energy-rich foods that can help combat caloric malnutrition, especially in rural areas. White beans, on the other hand, could be recommended in the diets of people with diabetes due to their low carbohydrate content. The results of this study are lower than those of [31], who obtained carbohydrate contents ranging from 54.05% to 64.50% for the seeds of seven cultivars of voandzou (Vigna subterranea) grown in Côte d'Ivoire.

The high phenolic compound content observed in bean flours sold in the Korhogo market, with values of 233.34 mg EAG/100g for white beans, followed by red beans at 169.86 mg EAG/100g and finally black beans at 151.08 mg EAG/100g, shows how rich in antioxidants the beans studied are. The values found in this study contradict the results [32], who observed that black and red beans are richer in phenolic compounds than white beans. However, antioxidant capacity varies widely depending on the color and origin of the seeds [33]. Thus, the differences observed in this study may reflect regional specificities of beans sold in Korhogo. These high levels of phenolic compounds are beneficial to the body as they help fight the free radicals that are constantly generated by our bodies. The flavonoid content of bean seed flour varies significantly depending on the variety. The red variety contains 56.33 mgEQ/100g, the black variety 54.20 mg EQ/100g, and the white variety 46.56 mgEQ/100g. Data from [32] confirm that red and black beans generally contain more flavonoids than white bean varieties. This superiority of red and black beans may be due to the strong pigmentation of their skins, which are often colored by a high concentration of flavonoids and other antioxidant compounds [34]. Thanks to the high flavonoid content in the flour of the beans studied, regular consumption could help neutralize free radicals, which helps reduce oxidative stress, protect cells from premature aging, and prevent certain chronic diseases such as cancer, diabetes, and cardiovascular disease.

The water absorption capacity of the different bean seed flours in this study ranges from 176.58% to 318.86%, with red bean seed flour having the highest water absorption capacity. The values obtained in this study are higher than those obtained by [31], with values ranging from 199.26% to 239. Water absorption capacity determines whether flours can be incorporated into aqueous food formulations [35]. The high water absorption capacity of the various bean flours studied, particularly red bean flour, suggests that may serve as functional ingredients in liquid and semi liquid foods like soups, gravies and baked products where water absorption/thickening is a critical factor [36].

The solubility indices of the different bean seed flours range from 19.05% to 34.60%, which shows that bean seed flours could be used in the formulation of infant foods, particularly red beans with 19.05% and black beans with 21.40%, which degrade less than white beans, which have a solubility index of 34.60% and can be used in bread or dough products.

The oil absorption capacity of different bean seed flours ranges from 81.65% for black beans, 89.60% for white beans, and 100.95% for red beans. These values are higher than those found by [37], who obtained values ranging from 58.33 to 68% for Voandzou flours grown in the Department of Korhogo. Good oil absorption capacity helps to emulsify and stabilize mixtures in nutritional food formulations or the agri-food industry [38]. The oil absorption capacity of different bean seed flours ranges from 81.65% for black beans, 89.60% for white beans, and 100.95% for red beans. These values are higher than those found by [37], who obtained values ranging from 58.33 to 68% for Voandzou flours grown in the Department of Korhogo. Good oil absorption capacity helps to emulsify and stabilize mixtures in nutritional food formulations or the agri-food industry [38].

The swelling power of bean seed flours ranged from 117% to 650.41%, with white bean seed flour having the highest Swelling power. The values obtained in this study are higher than those obtained by [37], with percentages ranging from 174.11% to 192.34% for Voandzou seed flours and similar to the results obtained by [39] 400 to 600% with cassava flour. The high swelling power of bean seed flour, particularly white bean seed flour, shows that this flour has a good capacity to absorb water from food formulations, which could directly influence the texture and consistency and, above all, increase the volume of finished products such as bread, cakes, and porridges made from these flours.

4. Conclusion

The objective of this study was to compare the nutritional and functional potential of flours derived from three varieties of beans consumed in the Korhogo department (Côte d'Ivoire) with a view to promoting their use. The results of this study showed that white bean seed flour was richer in protein, fiber, crude ash (and therefore minerals except iron), and polyphenols, and also had a higher swelling capacity and solubility index than red and black bean seed flours. The biochemical composition of white bean seed flour could be of nutritional interest for local food programs, particularly for the prevention of mineral deficiencies. Red bean seed flour had the highest iron and flavonoid content and a higher oil and water absorption capacity than black and white bean seed flours. This richness could be of nutritional interest for local food programs, particularly for the prevention of trace element deficiencies such as iron. Regular consumption could also help neutralize free radicals, protect cells from premature aging, and prevent certain chronic diseases such as cancer, diabetes, and cardiovascular disease. The interesting functional properties of white and red bean seed flours in this study make them ingredients of choice for the formulation of food products, including infant flours, bean-enriched doughnuts, and various baked goods. Finally, the black variety had the highest energy value compared to the red and white varieties. The high carbohydrate content of black bean seeds could contribute significantly to energy supply. Black beans would be an excellent choice for the formulation of energy-rich foods that could help combat caloric malnutrition, especially in rural areas. Overall, the flours from the seeds of the three bean varieties studied had low lipid content and could therefore be recommended for a low-fat diet.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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