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Effect of Different Processing Methods on the Nutritional Value of Red and White Bean Cultivars (*Phaseolus vulgaris* L.)

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Abstract: Among legumes, common bean plays significant role in the diet of Cameroonians. It is a good source of protein, fiber and micronutrients. However, bean contains substantial amount of antinutrients, which limit their utilization. This work evaluates the effect of different processing methods on the macronutrients, micronutrients and antinutrients contents in two bean cultivars (*Phaseolus vulgaris* L.). A survey was done in the city of Yaounde on the different processes applied on the cultivar before cooking. From the results of the survey, beans treatment were divided into six groups: raw, boiled, boiled with sodium bicarbonate, boiled with *Echinops giganteus* bark powder, soaked and boiled, soaked with sodium bicarbonate and boiled. The processed samples were analyzed for proximate and antinutrients composition using AOAC methods and minerals by atomic absorption spectrophotometry. The raw seed served as the control. The results of this study have shown that processing led to an increase significantly ($p<0.05$) in protein contents. The higher rate of protein were observed for soaked and boiled (25.82%) and boiled (24.23%) respectively for white and red bean. The fiber contents of soaked with sodium bicarbonate and boiled white bean were higher (8.39%) compare to fiber content values recorded for red bean cultivars samples. Fat contents are significantly ($p<0.05$) lower with all samples after processing. The carbohydrate content of the boiled with *Echinops giganteus* bark powder of red bean was the highest (59.26%) followed by boiled with sodium bicarbonate red bean 58.61%. Boiled with *Echinops giganteus* bark powder white bean cultivar had higher iron, zinc, potassium and magnesium while boiled red and white bean cultivar had higher copper levels. Soaked and boiled white bean cultivar had higher calcium while boiled with sodium bicarbonate red bean had higher sodium levels. Processing improved significantly ($p<0.05$) the nutritional value of the beans by reducing the antinutrient contents. Soaking with sodium bicarbonate and boiling were found to have the highest level of reduction effect on the tannin, oxalate and saponin particularly in the white bean cultivar. Red and white bean cultivars could be used as a food formulation material for infants and young children to prevent protein energy malnutrition.

Keywords: Nutritional Value, Soaking, Boiling, Bean Cultivars, Nutrition

1. Introduction

Protein energy malnutrition is still one of the major nutritional problems in the developing world. Adequate supply of animal proteins is difficult due to high cost and changing in consumers' attitudes towards animal-based proteins, as consumers are now more conscious in the food selection due to increased awareness about nutritional dependent health problems such as hypertension [1]. Thereby, food legumes constitute an important part of diet of a larger section of population in the developing world, as a good source of protein, carbohydrates, minerals and vitamins.

Being rich in protein, carbohydrate, calorific value, fiber and vitamins, legumes constitute staple food in many countries [2]. Among legumes, common bean (*Phaseolus vulgaris* L.) are widely consumed throughout the world alongside soybeans and peanuts [3].

Common beans have a great social and economic importance in Cameroon. They exist in different varieties distinguished by shape, color and size of the seeds. Shapes could be spherical, curve or kidney, colour usually ranges from green to creamy, red, white, grey, light brown and dark brown with a starchy flavor [4]. Common beans (*Phaseolus vulgaris* L.) are rich in protein (20-28%), carbohydrates (46%), fiber (15%) and micronutrients (Fe=34-89 mg/kg and Zn=21-54 mg/kg), but lower in lipid (1.5%) [5, 6]. However, bean cultivars contain several antinutritional factors such as condensed tannins, phytic acid, saponin, glucosides, trypsin and chymotrypsin which can also interfere in the nutritional value of beans through the formation of insoluble complexes with minerals, proteins and amides [7].

Subsequently, antinutrients will decrease the bioavailability and digestibility unless appropriate and affordable processing techniques are implemented [8]. Reducing these antinutrients to low concentrations would improve the nutritional quality of the beans. According to many authors, the health benefits of beans are associated with their processing methods. Beans should be cooked or processed before intake [9, 10].

Concerning different processing techniques, the studies conducted in Nigeria and in Brazil, [7, 11, 12] showed that germination, roasting, extrusion cooking, thermal processing and fermentation reduce the level of antinutrients, thus improve protein and starch digestibility of bean. However, in Cameroon, the use of these traditional methods of bean preparation is very scarce. This is partly due to their implementation time, food habits of population, lack of knowledge on nutritional benefits of these processes. Thereby, soaking and boiling are the most processing methods applied by the households.

Much information is available in the literature on nutritive value of 10 red bean cultivars [13], and mineral contents and antioxidant activities of some bean seeds [14], but information on effect of different processing methods on nutritional values of common beans is scanty. This study therefore evaluated the effect of different processing methods commonly used by the household on the nutrients and antinutrients content of both the red and white bean cultivars (*Phaseolus vulgaris* L.) for enhanced their potential in order to formulate infants and young children foodstuffs.

2. Materials and Methods

2.1. Sample Collection and Preparation

This was a descriptive study. The study have begun with a survey of bean consumers (traders, households) without distinction of sex in the city of Yaounde. The purpose of this survey was to identify the different cooking methods of beans commonly used in households in the city of Yaounde. Indeed, in January 2020 to September 2020 in Yaounde, two varieties (02) of dry beans and five (05) cooking methods were listed as commonly consumed by the populations.

Healthy red and white beans cultivars (*Phaseolus vulgaris* L.) have been bought from a local market in the city of Yaounde and then identified at the Agricultural Institute of Research for the Development of Foumbot station, West region of Cameroon under DOR 701 and MEX 142 respectively for red and white bean cultivars. These cultivars were transported to the laboratory of Food Science and Metabolism where they were sorted by removing dirt and broken beans. Then, they were washed thoroughly, to remove soil and all foreign particles. The seeds obtained were divided into 6 batches. The first batch was used for raw sample analysis (samples 1 and 2), second batch was boiled (samples 3 and 4), third batch was boiled with sodium bicarbonate (samples 5 and 6), fourth batch was boiled with powder of *Echinops giganteus* bark (samples 7 and 8), fifth batch was soaked and boiled (samples 9 and 10) and then sixth batch was soaked with sodium bicarbonate and boiled (samples 11 and 12). The raw samples served as the control.

For the first batch, 500g of each raw seeds were finely ground to a fine powder with a Kenwood blender after washing and drying to a constant weight at 50°C for 72 hours with frequent turning. The resultant flour was packaged in an airtight vessel in readiness for analysis. The vessel was appropriately labelled. For the second batch, 500g of bean seeds of each variety were boiled at 100°C for 1h30mn in 2.5L of distilled water in the proportion of 1:5 (w/v). The cooked seeds were dried to a constant weight at 50°C for 72 hours with frequent turning. The resultant flour was packaged in an airtight vessel in readiness for analysis. The vessel was appropriately labelled. For the third batch, 500g of bean seeds of each variety were boiled at 100°C with 15g of sodium bicarbonate for 1h30mn in 2.5L of distilled water in the proportion of 1:5 (w/v). The cooked seeds were dried to a constant weight at 50°C for 72 hours with frequent turning. The resultant flour was packaged in an airtight vessel in readiness for analysis. The vessel was appropriately labelled. For the fourth batch, 500g of bean seeds of each variety were boiled at 100°C with 15g of powder of *Echinops giganteus* bark for 1h30mn in 2.5L of distilled water in the proportion of 1:5 (w/v). The cooked seeds were dried to a constant weight at 50°C for 72 hours with frequent turning. The resultant flour was packaged in an airtight vessel in readiness for analysis. The vessel was appropriately labelled. For the fifth batch, 500g of bean seeds of each variety were firstly soaked in distilled water in a 1:5 proportion (w/v) for 8 hours at room temperature 28°C. Subsequently, the soaking water was removed. Secondly, the soaked bean seeds were boiled at 100°C for 1h30mn in 2.5L of distilled water in the proportion of 1:5 (w/v). The cooked seeds were dried to a constant weight at 50°C for 72 hours with frequent turning. The resultant flour was packaged in an airtight vessel in readiness for analysis. The vessel was appropriately labelled. For the sixth batch, 500g of bean seeds of each variety were soaked in 2.5L of distilled water in a 1:5 proportion (w/v) with 15g of sodium bicarbonate for 8 hours at room temperature 28°C. Then, the soaked bean seeds (without removed soaking water) were boiled at 100°C for 1h30mn. The cooked seeds were dried to a constant weight at 50°C for 72 hours with frequent turning. The resultant flour was packaged in an airtight vessel in readiness for analysis. The vessel was appropriately labelled.

2.2. Analysis

Moisture, total nitrogen, crude lipid, crude fiber, ash and carbohydrates were investigated using standard methods of Association of Official Analytical Chemists [15]. The samples were analyzed in triplicate.

2.2.1. Proximate Composition

The moisture was determined in an oven set at 105°C, according to standard procedures detailed by AOAC (Association of Official Analytical Chemists, 2005) [15]. The total nitrogen content was determined by the Kjeldahl method, as described by AOAC, and the protein content was calculated by multiplying result by 6,25. Crude lipid content was evaluated by Soxhlet extraction according to the method described by AOAC [15] using hexane as the extractor. The ash content was determined by calcination in a furnace at 550°C using the method described by AOAC [15]. The total fiber content was determined gravimetrically after delipidation of bean powder using the method described by AOAC [15].

2.2.2. Mineral Analysis

The mineral contents (iron, zinc, magnesium, phosphorus and calcium) of the different samples were carried out by AOAC method N°968.08 [16]. About 100 g of powder for each raw and cooking bean seeds cultivars were oven dried at 105°C for 72 hours. After drying, 5g were separately weighed into crucibles and dry ashed in muffle furnace maintained at 550°C for 24 hr. The ash was cooled in desiccators and then weighed. After weighing, the ash was dissolved in a solution of 1:1 ratio of H_2O:HCl, in which the concentration of the final mixture was 6N HCl. Iron, zinc, magnesium, phosphorus and calcium were determined by atomic absorption spectrophotometer (Shimadzu UNICAM 919, England) when total phosphorus concentration was measured by colorimetric spectrophotometer after incubation with Molybdo-vanadate solution. Potassium and sodium were determined by digesting the ash of the samples with perchloric acid and nitric acid, and then taking the readings on Jenway digital flame photometer/spectronic 20 [17].

2.2.3. Antinutrients Analysis

The phytate content was determined by titration with iron III solution after acid digestion [18]. The total oxalate content was assessed by titration with $KMnO_4$ after acid digestion [19]. Tannins were perform using ferric reagent in an acidic alcoholic medium and gallic acid as standard [20]. The absorbance was read at 550 nm. Saponin content was determined by weight difference after extraction in solvent [21].

2.3. Statistical Analysis

Data were expressed as mean ± standard deviation of triplicate measurements. Analysis of variance (ANOVA) and the comparison of means (Tukey's test, $P<0.05$) were applied using IBM/SPSS 20.0 software (Statistical Package of Social Science) for Windows.

3. Results

3.1. Proximate Composition of the Seeds

Table 1 below showed the proximate composition of the seeds according to the different processes, expressed in g/100g DM. It appeared that soaked and boiled white bean, soaked with sodium bicarbonate and boiled white bean and boiled red bean have significantly contents in proteins (25.82±0.45g/100g DM; 24.87±0.00g/100g DM and 24.23±0.90g/100g DM respectively). Fiber contents are significantly higher with soaked with sodium bicarbonate boiled white bean (8.39±0.21g/100g DM), soaked and boiled white bean (7.90±0.13g/100g DM). Lipid contents are significantly lower with all samples but contents are significantly higher with raw red bean (4.36±0.03g /100g DM), raw white bean (4.49±0.21g/100g DM) and boiled red bean (3.85±0.10g/100g DM). Ash contents are significantly higher with raw white bean (6.30±0.19g/100g DM), boiled with sodium bicarbonate white bean (4.02±0.09g/100g DM) and boiled with *Echinops giganteus* bark powder white bean (3.72±0.20 g/100g DM). The carbohydrate content of seeds is 64.67% (raw red bean), 55.56% (raw white bean), 59.26% (boiled with *Echinops giganteus* bark powder red bean) and 57.95% (boiled with sodium bicarbonate white bean).

Table 1. *Proximate composition of raw and processed bean cultivars (Phaseolus vulgaris L).*

Samples	Moisture (g/100g DM)	Proteins (g/100g DM)	Lipids (g/100g DM)	Crude fibre (g/100g DM)	Ash (g/100g DM)	Carbohydrates (g/100g DM)
Sample 1	7.93±0.79^{a}	14.06±1.84^{a}	4.36±0.03^{ef}	4.42±0.06^{a}	3.86±0.06^{de}	64.67±0.80^{c}
Sample 2	8.85±0.45^{ab}	18.49±0.00^{ab}	4.49±0.21^{f}	5.47±0.05^{b}	6.30±0.19^{f}	55.56±2.10^{b}
Sample 3	8.47±0.44^{ab}	24.23±0.90^{cde}	3.85±0.10^{de}	6.95±0.09^{e}	3.59±0.15^{cd}	52.65±0.61^{a}
Sample 4	9.74±0.35^{b}	22.64±3.15^{bcde}	3.54±0.31^{cd}	6.56±0.11^{de}	3.40±0.01^{bc}	56.24±0.70^{b}
Sample 5	8.64±0.16^{ab}	21.05±0.90^{bcd}	2.99±0.38^{bc}	6.04±0.11^{c}	3.47±0.16^{bc}	58.61±0.62^{b}
Sample 6	9.29±0.46^{ab}	19.77±0.00^{bc}	3.47±0.25^{cd}	6.13±0.09^{c}	4.02±0.09^{e}	57.95±1.27^{b}
Sample 7	8.73±0.15^{ab}	19.13±0.90^{b}	2.44±0.04^{b}	6.92±0.09^{e}	3.38±0.08^{bc}	59.26±0.93^{b}
Sample 8	8.89±0.76^{ab}	22.32±0.00^{bcd}	3.33±0.11^{cd}	4.53±0.18^{a}	3.72±0.20^{cde}	57.46±0.83^{b}
Sample 9	9.08±0.15^{ab}	20.72±0.45^{bcde}	2.52±0.26^{b}	5.95±0.04^{c}	2.72±0.30^{a}	57.96±0.68^{b}

Samples	Moisture (g/100g DM)	Proteins (g/100g DM)	Lipids (g/100g DM)	Crude fibre (g/100g DM)	Ash (g/100g DM)	Carbohydrates (g/100g DM)
Sample 10	9.55±1.27[ab]	25.82±0.45[c]	1.66±0.13[a]	7.90±0.13[f]	2.67±0.22[a]	51.79±0.99[a]
Sample 11	8.63±0.41[ab]	23.27±0.45[cde]	2.42±0.08[b]	6.24±0.15[cd]	3.16±0.05[b]	56.14±1.10[b]
Sample 12	9.05±0.97[ab]	24.87±0.00[de]	3.55±0.25[cd]	8.39±0.21[g]	3.17±0.04[b]	50.94±1.32[a]

Values are means ± SD of triplicate determinations, DM=dry matter basis. Means within the same column with different superscripts significantly different at p<0.05. Sample 1=raw red bean, Sample 2=raw white bean, Sample 3=boiled red bean, Sample 4=boiled white bean, Sample 5=boiled with sodium bicarbonate red bean, Sample 6=boiled with sodium bicarbonate white bean, Sample 7=boiled with *Echinops giganteus* bark powder red bean, Sample 8=boiled with *Echinops giganteus* bark powder white bean, Sample 9=soaked and boiled red bean, Sample 10=soaked and boiled white bean, Sample 11=soaked with sodium bicarbonate and boiled red bean, Sample 12=soaked with sodium bicarbonate and boiled white bean.

3.2. Mineral Analysis of the Seeds

Table 2 below showed the iron, zinc, calcium, potassium sodium, magnesium copper contents of red and white bean cultivars according to the different processes, expressed in mg/100mg DM. It noted that the iron content is 7.29% (raw red bean), 8.10% (raw white bean), 8.66% (boiled with *Echinops giganteus* bark powder white bean) and 5.62% (boiled with sodium bicarbonate red bean). The calcium composition is 106% (raw red bean), 128% (raw white bean), 128% (boiled red bean and soaked and boiled red bean), and 222% (soaked and boiled white bean). Zinc content is 2.88% (raw red bean), 3.06% (raw white bean). Zinc composition is significantly higher (p<0.05) with boiled with *Echinops giganteus* bark powder white bean (3.59%) and boiled white bean (3.34%) respectively. Of all the minerals evaluated, potassium is the most abundant having a value range of 1580% (raw red bean), 1670% (raw white bean), 1500% (boiled with *Echinops giganteus* bark powder white bean) and 1290% (boiled red bean).

Table 2. *Mineral content of raw and processed bean cultivars (Phaseolus vulgaris L).*

Samples	Fe (mg/100g DM)	Ca (mg/100g DM)	Zn (mg/100g DM)	Cu (mg/100g DM)	K (mg/100g DM)	Na (mg/100g DM)	Mg (mg/100g DM)
Sample 1	7.29±0.00[f]	106.00±0.00[a]	2.88±0.00[de]	0.33±0.01[a]	1580.00±0.01[g]	1.63±0.00[a]	193.00±0.00[i]
Sample 2	8.10±0.00[j]	128.00±0.00[b]	3,06±0,08[g]	0.65±0.00[b]	1670.00±0.00[h]	1.77±0.00[b]	193.00±0.00[i]
Sample 3	7.01±0.00[e]	128.00±0.00[b]	2.93±0.00[e]	0.80±0.00[d]	1290.00±0.00[e]	3.92±0.00[d]	168.00±0.00[gh]
Sample 4	7.81±0.00[i]	204.00±0.00[c]	3.34±0.01[h]	0.81±0.00[c]	1320.00±0.01[e]	2.78±0.00[c]	166.00±0.00[ef]
Sample 5	7.62±0.02[h]	121.00±0.00[b]	2.54±0.00[b]	0.49±0.00[b]	1100.00±0.01[cd]	299.05±0.00[l]	166.00±0.00[f]
Sample 6	5.87±0.00[a]	121.00±0.00[b]	2.54±0.00[c]	0.49±0.00[a]	1100.00±0.02[cd]	270.45±0.0[k]	147.00±0.00[c]
Sample 7	7.52±0.00[g]	126.00±0.00[b]	2.83±0.00[cd]	0.65±0.00[c]	1140.00±0.00[d]	4.37±0.00[e]	159.00±0.00[d]
Sample 8	8.66±0.00[k]	213.00±0.00[d]	3.59±0.00[i]	0.49±0.00[a]	1500.00±0.00[c]	7.14±0.00[f]	172.00±0.00[h]
Sample 9	5.86±0.00[a]	128.00±0.00[b]	2.37±0.00[a]	0.49±0.01[b]	930.00±0.00[a]	8.99±0.00[h]	129.00±0.00[a]
Sample 10	6.50±0.00[c]	222.00±0.00[e]	3.23±0.00[h]	0.65±0.00[b]	1060.00±0.01[bc]	7.99±0.00[g]	161.00±0.00[de]
Sample 11	6.23±0.00[b]	121.00±0.00[b]	2.77±0.00[c]	0.65±0.00[c]	1020.00±0.02[b]	109.92±0.00[j]	134.00±0.00[a]
Sample 12	6.92±0.00[d]	201.00±0.00[c]	3.23±0.00[h]	0.65±0.00[b]	1060.00±0.00[bc]	92.64±0.00[i]	140.00±0.00[b]

Values are means ± SD of triplicate determinations, DM=dry matter basis. Means within the same column with different superscripts significantly different at p<0.05. Sample 1=raw red bean, Sample 2=raw white bean, Sample 3=boiled red bean, Sample 4=boiled white bean, Sample 5=boiled with sodium bicarbonate red bean, Sample 6=boiled with sodium bicarbonate white bean, Sample 7=boiled with *Echinops giganteus* bark powder red bean, Sample 8=boiled with *Echinops giganteus* bark powder white bean, Sample 9=soaked and boiled red bean, Sample 10=soaked and boiled white bean, Sample 11=soaked with sodium bicarbonate and boiled red bean, Sample 12=soaked with sodium bicarbonate and boiled white bean.

The copper contents are 0.33% (raw red bean), 0.65% (raw white bean), 0.80% (boiled red bean) and 0.81% (boiled white bean) (table 2). The sodium contents are 1.63 (raw red bean), 1.77 (raw white bean), 299 and 270mg/100g DM (boiled with sodium bicarbonate red and white bean respectively). The magnesium content of bean cultivars is 193 (raw red and white bean), 166 (boiled with sodium bicarbonate red bean) and 172mg/100g DM (boiled with *Echinops giganteus* bark powder white bean) (Table 2).

3.3. Antinutrients Analysis of the Seeds

Table 3 below showed the antinutrient contents of red and white bean cultivars according to the different processes, expressed in mg/100g DM.

Table 3. *Antinutrient content of raw and processed bean cultivars (Phaseolus vulgaris L).*

Samples	Oxalate (mg/100g DM)	Phytate (mg/100g DM)	Tanin (mg/100g DM)	Saponin (mg/100g DM)
Sample 1	0.30±0.01[d]	0.10±0.00[bc]	0.28±0.04[c]	4.60± 0.35[f]
Sample 2	0.29±0.02[cd]	0.11±0.00[d]	0.16±0.04[b]	3.90 ± 0.14[d]
Sample 3	0.28±0.03[ab]	0.078±0.01[abc]	0.10±0.01[ab]	1.71 ± 0.10[c]
Sample 4	0.27±0.01[cd]	0.10±0.01[bcd]	0.06±0.00[a]	1.12 ± 0.02[ab]
Sample 5	0.26±0.00[bcd]	0.08±0.00[ab]	0.05±0.01[a]	1.09 ± 0.00[ab]
Sample 6	0.26±0.00[bcd]	0.09±0.00[bcd]	0.04±0.00[a]	1.02 ± 0.01[ab]
Sample 7	0.25±0.01[bc]	0.069±0.00[ab]	0.05±0.00[a]	1.35 ± 0.10[bc]

Samples	Oxalate (mg/100g DM)	Phytate (mg/100g DM)	Tanin (mg/100g DM)	Saponin (mg/100g DM)
Sample 8	0.26±0.00^{bcd}	0.06±0.00^{a}	0.03±0.00^{a}	1.18 ± 0.04^{ab}
Sample 9	0.28±0.00^{cd}	0.07±0.00^{ab}	0.042±0.00^{a}	0.93 ± 0.01^{ab}
Sample 10	0.24±0.00^{abc}	0.09±0.00^{abcd}	0.03±0.01^{a}	0.85 ±0.01^{a}
Sample 11	0.22±0.02^{ab}	0.08±0.00^{ab}	0.04±0.00^{a}	0.90 ± 0.00^{ab}
Sample 12	0.19±0.00^{a}	0.078±0.00^{abc}	0.02± 0.00^{a}	0.82 ±0.04^{a}

Values are means ± SD of triplicate determinations, DM=dry matter basis. Means within the same column with different superscripts significantly different at p<0.05. Sample 1=raw red bean, Sample 2=raw white bean, Sample 3=boiled red bean, Sample 4=boiled white bean, Sample 5=boiled with sodium bicarbonate red bean, Sample 6=boiled with sodium bicarbonate white bean, Sample 7=boiled with *Echinops giganteus* bark powder red bean, Sample 8=boiled with *Echinops giganteus* bark powder white bean, Sample 9=soaked and boiled red bean, Sample 10=soaked and boiled white bean, Sample 11=soaked with sodium bicarbonate and boiled red bean, Sample 12=soaked with sodium bicarbonate and boiled white bean.

The oxalate contents are 0.30% (raw red bean), 0.29% (raw white bean), 0.22% (soaked with sodium bicarbonate and boiled red bean) and 0.19% (soaked with sodium bicarbonate and boiled red bean) (Table 3). The phytate contents are 0.10 (raw red bean), 0.11 (raw white bean), 0.069 and 0.06mg/100g DM (boiled with *Echinops giganteus* bark powder red and white bean cultivars respectively). The tannin contents are 0.28 and 0.16mg/100g DM (raw and white bean respectively), 0.04 and 0.02mg/100g DM (soaked with sodium bicarbonate and boiled red and white bean respectively). The saponin contents are 4.60% (raw red bean), 3.90% (raw white bean), 0.90 and 0.82% (soaked with sodium bicarbonate and boiled red and white bean respectively) (Table 3). It appeared that all the processing methods led to significant reduction (p<0.05), in the levels of all the antinutrients (oxalates, phytates, tannins, saponins).

4. Discussion

Proximate analysis of food is of great importance in that it accounts for the food quality and it is usually the basis for the establishment of nutritional quality of food and its acceptability by consumers [22]. In order to improve the nutritional quality of beans, methods such as boiling, soaking and boiling, boiling with sodium bicarbonate, boiling with *Echinops giganteus* bark powder and soaked with sodium bicarbonate and boiling are the cooking processing commonly used by households in the city of Yaounde. The efficacy of these processes varies depending on the cultivar and treatment. All of these processes used reduce efficacy antinutrients contents [7] and lead to a considerable loss of macronutrients (except proteins) and minerals.

The proximate composition of the red and white bean cultivars are shown in Table 1. All the bean samples are low in moisture and fell within the recommended range of 0-13.5% [1]. The moisture content of the samples ranges between 7.93% in the raw red bean to 9.08% in the soaked and boiled red bean and 8.85% in the raw white bean to 9.74% in the boiled white bean sample. There was no significant difference (p>0.05) in the moisture content of all processed red and white bean samples. However, the value for the moisture content in the boiled white bean (9.74%) was higher than the moisture value of others samples. Cooking increased the moisture of the different samples of beans and this could be due to the absorption of water during soaking and cooking. The raw bean cultivars can be stored for a long period and this underscores its long shelf life and less susceptibility to microbial attack [13]. These values were similar to those reported by Oraka et al. [23] on raw, boiled roasted and autoclaved lima beans (9.21%, 10.21%, 8.25% and 9.85% respectively).

Protein contents in the red and white bean samples ranged between 14.06% in the raw red bean to 25.82% in the soaked and boiled white bean cultivars. All the processing methods have increased the protein contents both red and white beans. This could be justified by changes in the association and dissociation properties of proteins caused by heating. During cooking, there is disintegration of the crude protein into amino acids and therefore the heat treatment induces changes in the structure of the proteins, which can inactivate the antinutrients, thus increasing the digestibility and the biological values of the protein of the bean [13]. Similar result on increasing of protein content during cooking have been reported in Nigeria [2] in raw and processed velvet beans. However, different results on reduction of protein content during processing such as dehulling and cooking have been reported in two cultivars of beans (Vigna unguiculata and Vigna angustifoliata) [11].

Lipid content in the red and white bean samples ranged between 4.36% in the raw red bean to 1.66% in the soaked and boiled white bean. All the samples (raw and cooking) red and white beans contained low fat. Beans are not a good source of lipid. Low lipid content in the beans is an advantage, as this will reduce the risk of heart attack and increased blood cholesterol level [11]. Decreased fat content in the soaking and boiling samples might be due to loss of total solids during soaking prior to further processing and denaturation of the fat by heat processing and leaching into the processing water [24]. These results of lipid contents were higher compared to those shown in Ghana on five Lima bean accessions [25].

The crude fibre contents in the red and white bean cultivars ranged between 4.42% in the raw red bean to 8.39% in the soaked with sodium bicarbonate and boiled white bean. Processing also increased the crude fibre in the all batches except for the boiled with *Echinops giganteus* bark powder white bean where crude fiber was low (4.53%). The difference between these treatments was statistically significant (p<0.05). The high rate of crude fibre in the processed sample could be explain by the fact that heat treatments can have variable effects on crude fibre and that cooking causes disruption of the cellular components of beans (cellulose, hemicellulose, lignin, pectin and gums). The cooking process results in interactions between proteins and lipids and it leads to qualitative and quantitative changes in the composition of total fibre of cooked foods compared to that of raw foods [7]. Many authors found a crude fiber value of 2%, 3%, 6.81%, 6.96% and 9.21% in Nigeria Lima beans (*Phaseolus lunatus*) soaked at different time [26].

The ash content of these cultivars varied from 2.72% in soaked and boiled red bean to 6.36% in raw white bean. There was no significant difference in the ash content of soaked and boiled red and white bean, and soaked with sodium bicarbonate and boiled both red and white bean cultivars. Low ash content in the bean might be due to leaching of salts and minerals into the cooking water [1]. The ash content of the investigated samples was higher than those of Lima bean (*Phaseolus Lunatus*) flour (3.94-4.82%) [23].

The key function of carbohydrate in the body is to provide energy, which is responsible for doing various day-to-day activities [22]. The range of carbohydrate found in all samples in the current study varied from 50.94% (soaked with sodium bicarbonate and boiled white bean) to 64.67% (raw red bean). All the processing methods increased the carbohydrate content in the white beans except for soaked and boiled white bean and soaked with sodium bicarbonate and boiled white bean. Processing softens the cellulose, causes starch granules to break down and makes starch more available [1]. The carbohydrate content of the current study was higher than the value (57.08%) reported for full flat flour of Lima bean (*Phaseolus Lunatus*) [27]. However, it was observed that all the processing methods decreased the carbohydrates content in the red beans. According to [28], that reduction of the amounts of available carbohydrates could be due by the fact that carbohydrates being the water soluble compounds and then, they have been hydrolyzed and diffused in the soaking and cooking water. These values are close (51% to 41%) to those reported for the processed Velvet beans (*Mucuna Pruriens*) [2].

The raw and processed red and white beans contained appreciable amount of mineral with potassium being the most abundant. This implies that the incorporation of beans into diet of people who takes diuretics to control hypertension could be beneficial [29]. The results obtained for the two cultivars of beans (red and white) in Table 2 are in agreement with the findings of Adegunwa et al. [12] and Kwuimgoin et al. [14]. The two cultivars of beans (red and white) raw and processed are good sources of potassium, magnesium, copper, calcium, iron and zinc with potassium being the most abundant. The iron content ranged from 7.29% (raw) to 5.86% (soaked and boiled) and from 8.10% (raw) to 5.87% (boiled with sodium bicarbonate) for the red and white bean cultivars respectively. There were significant reduction in iron content in the processed samples except for the process with *Echinops giganteus* bark powder. *Echinops giganteus* bark powder is rich in iron [30], which could explain the high rate of iron content in the samples processed with this bark powder. Several authors found iron levels in 100g ranging from 11.5 mg to 7.4 mg [31]. Iron is required for oxygen to travel to tissues and organs. It helps to carry oxygen throughout the body in form of heamoglobin and myoglobin, it is an integral part of many proteins and enzymes and it also helps in energy metabolism [32].

The range of Ca found in red bean samples in the current study varied from 106% (raw) to 128% (boiled, soaked and boiled) and in the white beans samples, it ranged from 128% (raw) to 222% (soaked and boiled). The findings showed a significant ($p<0.05$) increase of calcium contents in the processed samples. Calcium is known as a macroelement necessary for the development of teeth, bones and the release of hormones [33]. The Ca levels found in the present study are higher than the values (60%-80%) reported for two cultivars of beans (*Vigna unguiculata and Vigna angustifoliata*) by Yellavila et al. [25].

Sodium levels in the samples ranged from 1.63% (raw) to 299.05% (boiled with sodium bicarbonate) and 1.77% (raw) to 270.45% (boiled with sodium bicarbonate) for red and white bean cultivars respectively. Our findings revealed a significant increase in sodium contents in the cooked samples particularly with the sodium bicarbonate. Sodium is ingested frequently in food in the form of sodium chloride (cooking salt) although it is naturally present in food. The sodium content of the investigated samples was lower than those of white bean seeds (*Phaseolus vulgaris* L.) in Egypt (322-819%) [34].

The zinc levels ranged from 2.37% (soaked and boiled) to 2.93% (boiled) and 2.54% (boiled with sodium bicarbonate) to 3.59% (boiled with *Echinops giganteus* bark powder) for red and white beans respectively. Zinc level was higher in the cooked white bean than red bean. Studies in the literature show zinc values ranging from 2.48% to 5.12% [1, 22] in different processed of the Lima beans. Zinc boosts the health of our hairs, plays a role in the proper functioning of some sense organs such as ability to taste and smell [7].

Copper was the least abundant and was significantly lower than all the mineral analyzed. The copper content varied from 0.33% (raw) to 0.80% (boiled) and 0.49% (boiled with sodium bicarbonate and boiled with *Echinops giganteus* bark powder) to 0.81% (boiled) for red and white beans respectively. Copper had a significant difference between the raw and processed bean in each cultivars. The average copper content in white bean seeds (*Phaseolus vulgaris* L.) in Egypt [34] were higher than the average levels of copper found in the current study.

The magnesium content varied from 129% (soaked and boiled) to 193% (raw) and 140% (soaked with sodium bicarbonate and boiled) to 193% (raw) for red and white bean seeds respectively with white bean having the higher value. All of these processes have reduced magnesium content in the two cultivars. This range of value falls within the range reported by [35], which is 189.91% to 195.33% of sample. Our findings were lower compared to those found in West Cameroon (442.26 and 714.42%) on small white grain respectively cooked and raw. Magnesium is required for bone formation, which maintains the electrical potential in nerves [14].

Potassium was the most abundant and was higher than all the minerals analyzed. The amount of potassium ranged from 930% (soaked and boiled) to 1580% (raw) in red beans and 1060% (soaked and boiled and soaked with sodium bicarbonate and boiled) to 1670% (raw) in white beans. Indeed, findings of [36], showed that organic black beans (*Phaseolus vulgaris* L.) from Rio de Janeiro state ranged from 1351% (nonorganic) to 1354% (organic) in coastal region and 1368% (nonorganic) to 1461% (organic) in metropolitan region. Potassium is nutritionally important for pH regulation and the proper functioning of carbohydrate and protein metabolism [37]. For this reason bean seeds are an excellent food to cover daily potassium requirements. Variations in the micronutrient content of cultivars can be attributed to a number of factors: plant characteristics, such as plant age, maturity, species, variety, cultivar, environmental features, such as climate, soil, rainfall, and season; and processing factors, such as storage time, temperature, method of preservation, and preparation of food. Therefore, it appeared that the grains analyzed in this study had similar characteristics [7].

Antinutrients are found at some level in almost all foods. However, their levels are reduced through various traditional methods [38]. The findings of this study revealed that all the processing methods significantly ($p<0.05$) reduced antinutrient contents in red and white bean seeds. The amount of oxalates ranged from 0.30% (raw) to 0.22% (soaked with sodium bicarbonate and boiled) in red bean and 0.29% (raw) to 0.19% (soaked with sodium bicarbonate and boiled) in white bean. The high level of reduction of oxalate in this study is similar to the range (1.48% to 0.04%) reported by [39], for cooking Canavalia Plagiosperma piper seeds. In the literature, it was reported that oxalates reduces the availability of essentials nutrients [40]. Diet high in oxalate has been reported to increase the risk of development of kidney stone [41].

Tannin content ranged between 0.28% (raw) to 0.04% (soaked with sodium bicarbonate and boiled) and 0.16% (raw) to 0.02% (soaked with sodium bicarbonate and boiled) in red and white beans respectively. Processing with sodium bicarbonate significantly reduced the tannin content in red and white beans (more than 90%). Many authors observed the similar results on reduction of tannin in the biofortified carioca bean (2.15% to 0.02) and the common bean (0.42 to 0.03%) [5]. According to Toledo et al. [42], tannins can interact with protein and interfere with digestibility of beans, decreasing the hydrolysis of phaseolin. Soaking and cooking are processing that can influence the amount of tannins. Cooking can promote a significant decrease in tannins of bean and when cooking is prepared without using the soaking water, this reduction is even more expressive than when the beans are cooked with the soaking water or are not soaked [5]. Soaking, followed by cooking, is the most recommended treatment for the reduction of tannins in legumes [42].

Concerning to the determination of phytates, the concentration varied from 0.10% (raw) to 0.069 (boiled with *Echinops giganteus* bark powder) in the red bean and 0.11% (raw) to 0.078% (soaked with sodium bicarbonate and boiled) in white bean. These values are less than that of *G. africanuum* (90.68%) and *G. buchholzianum* (120.82%) [44]. According to Fabbri et al. [45], boiling reduces phytates content of vegetables. However, phytates are heat-resistant and not as easily degraded by boiling. But a longer cooking time often results in greater reduction of antinutrients. Boiling with *Echinops giganteus* bark powder and soaking with sodium bicarbonate and boiling were found to significantly reduced ($p<0.05$) all the phytates evaluated in the red and white bean seeds.

Saponin contents varied from 4.60% (raw) to 0.90% (soaked with sodium bicarbonate and boiled) and 3.90% (raw) to 0.82% (soaked with sodium bicarbonate and boiled) in red and white beans respectively. These values was higher than the value (50.05%) reported for boiling and roasting kidney bean seeds flour in Nigeria [8]. Soaking with sodium bicarbonate and boiling were found to significantly reduced ($p<0.05$) all the phytates evaluated in the red and white bean samples. Saponins are known for their foaming properties in aqueous solution astringent taste and haemolytic activity on red blood cells [14]. Saponins are secondary metabolites with antibacterial and antithelmintic activites [46].

5. Conclusion

The effects of different processing methods on the nutritional value of red and white bean cultivars (*phaseolus vulgaris* L.) were successfully evaluated. In the present study, it was found that after processing methods, both the red and white bean cultivars are rich in nutrients (protein, fibre, ash, carbohydrate and minerals). Bean seeds are not a good source of lipids which is an advantage as this will reduce blood cholesterol level. The iron and zinc levels were low but could (if bioavailability is not affected) cover the daily requirements for children, men, women and pregnant women respectively. All the processing methods (boiled, boiled with sodium bicarbonate, boiled with *Echinops giganteus* bark powder, soaked and boiled, soaked with sodium bicarbonate and boiled) were effective in reducing the antinutrients evaluated both the red and white bean. Soaking with sodium bicarbonate and boiling was found to have the highest significant effect on the reduction of all the antinutrients evaluated. The results of this study are essential for infant and young children material food for foodstuffs.

Conflicts of Interest

All the authors do not have any possible conflicts of interest.

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