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Nutritional and Antinutritional Characteristics of Ten Red Bean Cultivars (*Phaseolus vulgaris* L.) from Cameroon

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Beans are nutritionally and economically important food crop in Cameroon. However, data on the nutritional value of the different red bean cultivars remain poorly known to consumers. The objective of this study is to characterize 10 red bean cultivars in order to determine theirs nutrients, minerals and antinutrients contents. Grains of raw and cooked beans were evaluated for proximate, mineral and antinutrients composition. Statistical analysis of the data was carried out using the ANOVA and the Tukey test ($p \le 0.05$). The results of chemical analysis of the raw and cooked cultivar bean revealed moisture content ranging from 4.19 to 12.34%, protein from 10.56 to 46%,. lipids from 5.31 to 7.38%, ash from 1.93 to 4.61%, fiber from 2.42 to 7.97% and carbohydrates 38.30 to 68.85%. Different bean cultivars showed statistically significant differences in minerals. The most abundant minerals in the samples were potassium (K) and calcium (Ca) with contents

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ranging from 565.17 to 912.99 mg/100g dry matter (DM) and 78.5 to 933.85 mg/100g DM respectively. Iron (Fe) and zinc (Zn) contents ranged from 1.89 to 4.19 mg/100g DM and 2.10 to 5.15 mg/100g DM respectively. Antinutrients contents ranging from 0.14 to 1.00%, 2.86 to 8.82%, 0.07 to 0.18% and 0.26 to 1.22% respectively for tannins, phytates. oxalates and saponins after treatment. After soaking associated with cooking, red beans cultivars were found to contain the least minerals contents and that treatment significantly reduced ($p<0.05$) all the antinutrients evaluated. Red beans cultivars are potential nutrients rich food material for food formulation.

Keywords: Red bean; chemical analysis; antinutrients analysis; nutrition.

1. INTRODUCTION

Malnutrition is a public health challenge especially in the developing countries of the world and micronutrient malnutrition affect majority of people, with its effect being more pronounced among the rural poor communities. Good nutrition involves consuming foods and supplements rich in essential nutrients that provide adequate energy, micronutrient and support growth and body maintenance [1]. In Cameroon, victims are mostly children less than five years (0 to 59 months more exposed to the risks of death), pregnant and lactating women. The Demographic and Health Surveys (EDSC-MICS) in Cameroon reported that 60% and 33% of children aged 6 to 59 months were anemic and stunted respectively [2]. This deficiency is associated in the reduction of resistance to the infectious diseases [3]. Moreover, micronutrient deficiencies impose a substantial health, economic and social burdens worldwide [2]. The recent FAO data have shown that almost 2 billion of people are undernourished and suffering from food insecurity. The highest prevalence of 675 million of people is in Africa [4].

To manage this situation, several strategies such as food diversification, food fortification and supplementation with micronutrients and vitamins have been prescribed and developed by the ministry of public health [2,3]. However, the prevalence of these micronutrient deficiencies remains high. The high cost of fortified nutritious proprietary complementary foods is always beyond the reach of most Cameroonian families hence many depend on inadequately processed traditional foods consisting mainly of unsupplemented cereal porridges made from maize, sorghum and millet [5]. Long term poor eating habits affect lifestyle and cause related chronic diseases including obesity, diabetes, cardiovascular diseases and some cancers. To prevent adult obesity or cancer, it is desirable that individuals acquire appropriate dietary habits in childhood [6]. Therefore, research for new dietary strategies becomes urgent and important in order to reduce the high rate of chronic diseases.

Beans are important dietary components with versatile health benefits [7]. They have great social and economic importance in Cameroon because they are one of the main sources of protein, plant-derived micronutrients, and minerals. Indeed, among legumes, common beans (*Phaseolus vulgaris* L.) play a significant role in human nutrition, being an important source of plant proteins, minerals, dietary fiber, low glycemic carbohydrates certain vitamins and exhibit, for this reason, high nutritional value. Beans have significant amount of both soluble and insoluble fiber; its soluble fiber helps in lowering blood cholesterol by creating more insulin receptor sites [7,8]. In addition, beans contain substantial amount of phenolic acids and flavonoids; some cultivars (red, and black) show also anthocyanins, such as delphinidin and cyanidin, that overall attribute them a very strong antioxidant and antiradical activities [9]. The use of locally available foods and foodstuffs are being encouraged as a means of dietary diversification in combating the high rate of micronutrient deficiencies. However, dry legumes contain several anti-nutritional factors such as glycosids, inhibitors, phytic acid, tanins, and lectins but some simple and inexpensive processing techniques such as soaking and cooking are highly efficient for the reduction of these anti-nutritional factors [8].

In Cameroon, much information are available in the literature on amino acids composition, in vitro antisickling and antioxidant activities of phenolic compound extracts from black bean seeds [10], but information on the nutrient content of raw and cooked red beans cultivar is scanty. Therefore, this research was aimed at determining the nutrients and antinutrients content of ten red bean (*Phaseolus vulgaris* L.) cultivars from Cameroon using both raw and cooked samples.

2. MATERIALS AND METHODS

2.1 Sample Collection and Preparation

Ten red bean cultivars (*Phaseolus vulgaris* L.) were purchased from Central, Sandaga and Dakar local markets in Douala, Mokolo, Mfoundi and Acaccia local markets in Yaounde and A and B local markets in Bafoussam. Then, the cultivars were identified under GLP-190C (speckled large red seed), GLP-190S (speckled large dark red seed), FEB192 (large red seed), DOR701 (small dark red seed), NUA99 (speckled medium red seed), MAC55 (big red seed), MAC33 (speckled big red seed), ECAPAN 21 (speckled medium red seed), NUV109-2 (small red seed) and X (medium red seed) (Fig. 1) at the Agricultural Institute of Research for the Development of Foumbot station (IRAD), West region of Cameroon in november 2018 to January 2019. The seeds were cleaned and extraneous materials carefully removed by hand sorting. Sample was divided into two parts in the ratio 1:2.

Depending on the preparation technique, the bean cultivars (*Phaseolus vulgaris* L.) were divided into the following treatment protocols: raw samples and cooked samples. The raw beans five hundred gram of the each raw seeds sample were finely ground to a fine powder with a Kenwood blender after washing and drying in an oven at 45 °C during 12 hours. The bean flour was stored in polyethylene bags, properly closed and kept refrigerated until analysis.

The cooked beans cultivars were first soaked in distilled water, in a 1:5 proportion (W/V) for 12 hours at room temperature 28°C. Subsequently, the soaking water was discarded and a new aliquot of water was added in the proportion of 1:2 (w/v). The beans were cooked in the pot at 100 °C for 2 hours on a hot plate until they became soft to touch. At the end of cooking time, the water was drained and the seeds were oven dried and were finely ground to a fine powder with a Kenwood blender. The bean flour was stored in polyethylene bags, properly closed and kept refrigerated until analysis.

2.2 Chemical Analysis

The twenty samples were analyzed in triplicate for moisture, total nitrogen, crude lipid, crude fiber and ash using standard methods of Association of Official Analytical Chemists (AOAC, 2005). The carbohydrate content was obtained by difference.

2.3 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) [11]. 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 [11] using hexane as the extractor. The ash content was determined by calcination in a furnace at 550 °C using the method described by AOAC [11]. The total fiber content was determined gravimetrically after delipidation of bean powder using the method described by AOAC [11].

2.4 Mineral Analysis

The mineral content (iron, zinc, magnesium, phosphorus sodium and calcium) of the samples was carried out by AOAC method Nº 968.08 [12]. About 100 g of powder for each raw and cooking bean seeds cultivars were oven dried at 105 °C for 24 hours. After drying 5 g 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 6NHCl. 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 [13].

2.5 Antinutrients Analysis

The phytate content was determined by titration with iron III solution after acid digestion [14]. The total oxalates content was determined by titration with KMnO4 after acid digestion [15]. Tannins were determined using ferric reagent in an acidic alcoholic medium and gallic acid as standard [16]. The absorbance was read at 550 nm. Saponins content was determined by weight difference after extraction in solvent [17].

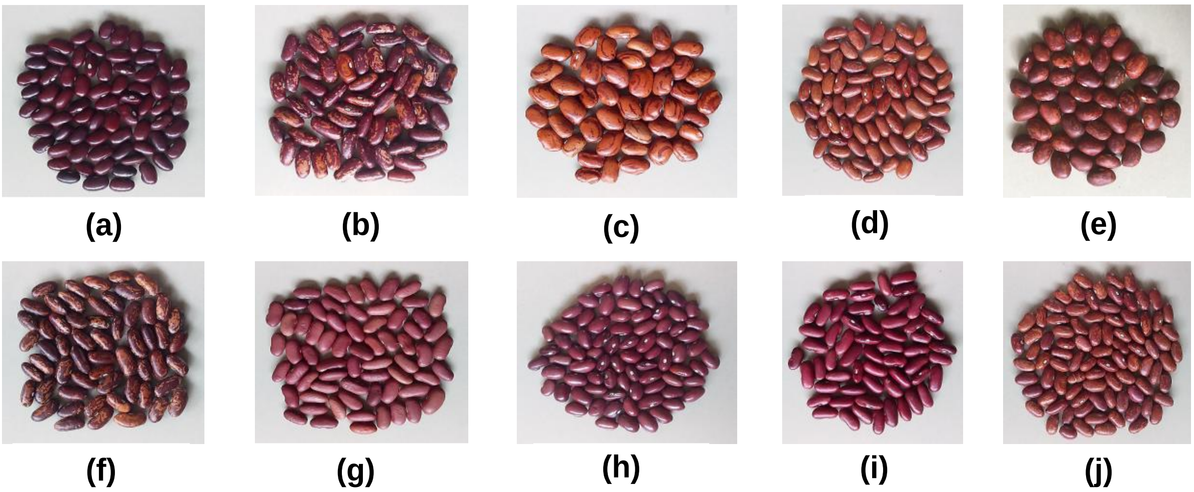

Fig. 1. Picture of ten red beans (*Phaseolus vulgaris* L.) cultivars from Cameroon
(a): DOR701 (small dark red seed); (b): GLP-190S (speckled large dark red seed); (c): MAC55 (big red seed); (d): NUA99 (speckled medium red seed); (e): MAC33 (speckled big red seed); (f): GLP-190C (speckled large red seed); (g): FEB192 (large red seed); (h): NUV109-2 (small red seed); (i): X (medium red seed); (j): ECAPAN 21 (speckled medium red seed)

2.6 Data 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

The results of proximate composition (moisture. protein. lipid. fiber. ash and carbohydrate) of the raw and cooked red bean cultivars are shown in Table 1. Results showed significant difference ($p < 0.05$) among samples. On the others hands, such differences were not significant within the raw or cooked red bean of the same cultivar. The average protein content was 10.56 to 46.00% in raw bean cultivars and 14.19 to 40.5% in cooked bean cultivars (Table 1). The ten cultivars were very low in fat and ash content (Table 1). The raw bean cultivar DOR701 had higher value of fat content 7.38%, while cooked bean cultivar X (unknown) had higher value of fat content 6.39% with significance difference in all the raw and cooked cultivars. The fiber content in the samples were ranged from 2.42 to 6.30% in the raw beans and 3.25 to 7.97% in the cooked beans (Table 1).The cooked cultivar having the higher amount. The carbohydrate content in the samples was ranged from 35.17 to 68.85% in raw beans and 38.30 to 59.86% in cooked beans (Table 1). Carbohydrates and proteins are major components of dry beans.

Minerals (Fe, Zn, Ca, P, Mg, K and Na) contents in raw and cooked bean seeds are presented in Table 2. It appeared that all the cultivars were very high in calcium, potassium, phosphorous, magnesium and iron. Of all the minerals evaluated, calcium is the most abundant having a value range of 1064.35 mg/100g in the raw (FEB192) to 933.85 mg/100g in the cooking (DOR701) cultivars. It is followed by potassium having a value ranged of 912.99 mg/100g in the cooking (MAC33) cultivar. Phosphorus content in the samples were ranged from 484.89 mg/100g in the raw (GLP190-S) cultivars and 415.28 mg/100g in the cooking (FEB192) cultivars. Magnesium content ranged from 418.06 mg/100 g in the raw (NUV109-2) cultivars to 272.29 mg/100g in the cooking (FEB192) cultivars. Iron content ranged from 8.63 mg/100g in the raw (NUA99) cultivar to 4.19 mg/100g in the cooking (GLP190-C) cultivars. Zinc content having a high value ranged of 7.77 mg/100g in the raw (NUV109-2) cultivar to 5.15 mg/100g in the cooking (FEB192) cultivars (Table 2).

Table 3 shows the level of antinutrients in the raw and cooking red bean cultivars samples. Phytate content in the samples was ranged from 4.80 (FEB192) to 10.06% (GLP190C) and from 2.86 (FEB192) to 8.82% (NUA99) respectively in the raw and cooked beans (table 3). Tannin content ranging from 0.84 (ECAPAN021) to 4.52% (DOR701) and from 0.14 (DOR701) to 1.00% (X). oxalate content ranging from 0.28

(GLP190C) to 0.67% (X) and from 0.07 (MAC55) to 0.18% (FEB192) and saponin content ranging from 0.52 (GLP190S) to 4.26% (DOR701) and from 0.26 (MAC55) to 1.22% (NUA1092) in the raw and cooked samples respectively. Cooking led to significant reduction in the levels of all the antinutrients ($p<0.05$).

4. DISCUSSION

4.1 Proximate Analysis

Beans provide significant amounts of protein and dietary fiber and are an excellent source of some minerals [18] as shown in Table 1. The proximate composition of the sample analyzed is shown in Table 1. The moisture content of the ten red bean cultivars analyzed was ranged from 4.19 to 7.89% in the raw cultivar to 6.06 to 12.34% in the cooked cultivar with the cooking seeds having a the higher value. All the cultivars showed no significant difference ($p > 0.05$). 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 beans cultivar can be stored for a long period of time and this underscores its long shelf life and less susceptibility to microbial attack [1]. Similar values of moisture content was obtained in seeds of brown and white beans in Nigeria (3.56 and 5.08%) [19]. But values were low when compared to those of two cultivars of beans (Vigna unguiculata and Vigna angustifoliata) which are others bean cultivars commonly consumed in Nigeria [1].

The crude protein content of the red bean cultivars was 10.56 to 46.00 g/100g DM for raw samples and 14.19 to 40.51 g/100g DM for cooked samples. Soaking combined with cooking improved significantly ($p < 0.05$) protein content (Table 1). 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 antinutritional factors. Thus increasing the digestibility and the biological values of proteins of the bean [20]. However, we noted that there is no significant difference between raw and cooked samples E and F. Also, crude protein content of red bean cultivar H remains high in the raw sample compared to the cooked sample. Variations in the protein content of different cultivars raw and cooked can be attributed to environmental, food habits or genetic factors related to each cultivar [21,22]. Similar results on increasing of protein content during cooking have been reported in processing wild kidney beans (*Canavalia ensiformis)* [23]. However. [24] have reported that cooking and roasting lead to reduction of protein content in African yam bean. Processing has also been found to reduce protein content but increase protein digestibility [25]. Protein enhances the repair and replacement of worn out tissues and also plays vital role in immune regulation and development of the body and its protection for the treatment of protein energy malnutrition [26]. The 10 red bean cultivars were high in protein content and can be good sources of plant protein.

Fat content in the red bean cultivars samples ranged between 5.04 to 6.39 g/100g DM and 5.60 to 7.38 g/100g DM in cooked and raw samples respectively (Table 1). However. fat levels in the cooked samples were significantly lower ($p< 0.05$) than in the raw samples. [18] found lower values (from 1.66 to 2.22%) to the data present in our study. This could be as a result of difference in the cooking methods used. cultivar characteristics and location where the cultivars were obtained. Beans are not a good source of fat. Fat provide strong energy and transports fat soluble vitamins like vitamins A. D. E and K [27]. Low fat content in the beans is an advantage as this will reduce the risk of heart attack and increased blood cholesterol level [28].

The carbohydrate content of our study ranged between 35.17 to 68.84 g/100 g DM and 38.31 to 59. 85 g/100g DM in raw and cooked samples respectively. Carbohydrates content of the investigated samples were lower than those of brown and white beans in Jos North [19]. but higher than the value reported for Brasil. Perola. and Pirata cultivar [18]. This reduction in carbohydrates could be due to the fact that they underwent irreversible chemical changes due to heat and hydration [29]. In addition. being water-soluble compounds. they were hydrolyzed and leached in cooking water [30]. On the others hands. the increase in carbohydrate content observed in some samples could be explained by the fact that soaking and cooking softened the cellulose. caused the starch granules to decompose and made the starch more available [31]. According to the [18], the key function of carbohydrate in the body is to provide energy which is responsible for doing various day to day activities. Food rich in carbohydrates provides more energy.

Table 1. Proximate composition of raw and cooked red beans (*Phaseolus vulgaris L.)* cultivars (g/100 g) (dry weight basis)

Cultivars		Moisture	Protein	Fat	Fibre	Ash	Carbohydrate
A	Raw	6.22±0.05^{a}	10.56±0.38^{a}	6.61±0.17^{fgh}	3.15±0.02^{b}	4.61±0.14^{g}	68.85±0.22^{e}
	Cooked	11.89±3.52^{a}	14.19±0.77^{ab}	6.15±0.12^{cdefg}	4.69±0.05^{h}	3.23±0.16^{d}	59.86±2.80^{de}
B	Raw	7.89±0.09^{a}	20.40±0.25^{bc}	6.35±0.05^{defg}	3.51±0.02^{c}	3.57±0.09^{ef}	58.29±0.29^{cde}
	Cooked	11.65±4.33^{a}	23.73±0.29^{cd}	5.44±0.16^{abc}	5.52±0.04^{i}	2.04±0.05^{ab}	51.62±4.09^{bcd}
C	Raw	5.66±0.04^{a}	23.58±0.38^{cd}	6.72±0.11^{gh}	3.09±0.02^{b}	3.95±0.03^{g}	56.99±0.51^{cde}
	Cooked	8.72±0.18^{a}	30.67±1.76^{ef}	5.31±0.15^{abc}	3.25±0.03^{b}	3.15±0.01^{d}	48.90±1.57^{abcd}
D	Raw	7.09±0.16^{a}	23.44±0.00^{cd}	6.52±0.27^{fgh}	4.66±0.03^{h}	4.81±0.03^{d}	53.48±0.17^{bcde}
	Cooked	8.13±0.06^{a}	40.51±0.77^{gh}	5.49±0.16^{abcd}	4.29±0.04^{ef}	3.27±0.03^{de}	38.30±0.58^{ab}
E	Raw	7.72±0.07^{a}	29.22±0.58^{def}	6.67±0.25^{gh}	6.30±0.04^{l}	3.74±0.02^{fg}	46.34±0.90^{abcd}
	Cooked	8.56±0.26^{a}	30.96±0.29^{ef}	5.98±0.18^{bcdefg}	4.16±0.06^{de}	2.03±0.02^{ab}	48.31±0.37^{abcd}
F	Raw	4.61±0.17^{a}	26.33±1.26^{cde}	7.38±0.14^{h}	4.42±0.03^{fg}	3.83±0.02^{fg}	53.43±1.20^{bcde}
	Cooked	6.44±0.17^{a}	26.62±0.29^{cde}	5.42±0.21^{abc}	5.96±0.02^{j}	2.73±0.02^{c}	52.83±0.22^{bcd}
G	Raw	5.70±0.06^{a}	28.07±0.77^{def}	6.48±0.05^{fg}	4.63±0.02^{h}	3.20±0.01^{d}	51.93±0.74^{bcd}
	Cooked	6.80±0.48^{a}	38.77±3.26^{g}	5.04±0.15^{a}	6.20±0.02^{kl}	2.72±0.02^{c}	40.47±2.88^{ab}
H	Raw	5.40±2.30^{a}	31.25±1.00^{ef}	5.60±0.20^{abcde}	2.42±0.01^{a}	3.25±0.04^{d}	52.08±3.19^{bcd}
	Cooked	12.34±7.84^{a}	22.86±0.29^{cd}	5.25±0.19^{ab}	7.97±0.06^{m}	2.25±0.04^{b}	49.33±7.88^{abcd}
I	Raw	7.00±0.57^{a}	34.43±0.58^{fg}	5.76±0.19^{abcdef}	3.98±0.04^{d}	3.62±0.01^{f}	45.21±0.52^{abcd}
	Cooked	12.09±7.45^{a}	34.43±0.29^{fg}	5.34±0.05^{abc}	3.30±0.11^{bc}	1.93±0.03^{a}	42.90±7.33^{abcd}
X	Raw	4.19±0.36^{a}	46.00±3.00^{h}	6.12±0.19^{bcdefg}	4.73±0.05^{h}	3.79±0.02^{fg}	35.17±3.13^{a}
	Cooked	6.06±0.00^{a}	30.67±1.26^{ef}	6.39±0.21^{efg}	6.02±0.06^{jk}	2.18±0.03^{ab}	48.69±1.11^{abcd}

Values are means ± SD of triplicate determinations. Different superscripts letters in the same column indicate a statistical difference ($p < 0.05$) between the cultivars. A= NUV-109-2; B= ECAPAN 021; C= GLP-190-C; D= MAC-55; E= MAC-33; F= DOR-701; G= FEB-192; H= GLP-190-S; I= NUA-99; X= unknown

Table 2. Mineral composition of raw and cooked red beans (*Phaseolus vulgaris L.)* cultivars (mg/100 g) (dry weight basis)

	Cultivars	Fe	Zn	Ca	Mg	P	K	Na
A	Raw	5.48±0.04^{i}	7.77±0.01^{p}	464. 23±0.04^{h}	418.06±0.03^{m}	462.34±0.03^{s}	748.28±0.03^{e}	110.3±0.01^{i}
	Cooked	3.39±0.02^{f}	2.93±0.01^{e}	142.42±0.02^{b}	127.68±0.03^{c}	251.72±0.02^{b}	658.37±0.05^{b}	88.21±0.03^{c}
B	Raw	4.01±0.02^{h}	4.61±0.02^{j}	384. 04±0.02^{e}	272.25±0.03^{h}	382.48±0.03^{n}	1022.12±0.04^{q}	133.24±0.03^{p}
	Cooked	2.60±0.02^{b}	2.50±0.01^{a}	78.5±0.02^{a}	77.86±0.03^{a}	263.68±0.01^{e}	867.17±0.04^{j}	112.45±0.03^{j}
C	Raw	7.61±0.02^{m}	4.22±0.02^{i}	392.24±0.02^{g}	272.24±0.02^{h}	337.41±0.03^{j}	808.62±0.02^{g}	121.48±0.07^{m}
	Cooked	4.19±0.02^{h}	2.10±0.01^{a}	384.20±0.02^{f}	223.73±0.03^{g}	256.8±0.02^{d}	794.22±0.04^{f}	110.17±0.03^{i}
D	Raw	6.13±0.03^{k}	5.79±0.01^{n}	272.77±0.02^{d}	320.82±0.02^{k}	339.06±0.03^{k}	1001.29±0.02^{p}	123.32±0.07^{o}
	Cooked	3.80±0.02^{g}	3.33±0.02^{f}	261.75±0.02^{c}	126.48±0.02^{b}	318.30±0.01^{g}	911.39±0.04^{l}	122.07±0.01^{n}
E	Raw	5.78±0.02^{j}	4.97±0.01^{k}	864.16±0.03^{lm}	295.28±0.03^{j}	406.63±0.03^{p}	1047.15±0.02^{r}	114.51±0.02^{k}
	Cooked	1.89±0.05^{a}	2.21±0.02^{b}	855.97±0.02^{k}	223.65±0.01^{g}	326.62±0.01^{h}	912.99±0.03^{m}	99.53±0.3^{g}
F	Raw	7.85±0.01^{n}	5.73±0.01^{n}	944.87±0.03^{q}	329.34±0.02^{l}	404.99±0.01^{o}	927.56±0.03^{n}	89.91±0.01^{d}
	Cooked	3.12±0.02^{e}	3.47±0.01^{g}	933.85±0.02^{o}	175.26±0.03^{e}	253.46±0.03^{c}	831.06±0.03^{i}	88.47±0.04^{c}
G	Raw	3.23±0.04^{e}	6.98±0.01^{o}	1064. 35±0.03^{r}	280.25±0.02^{i}	434.02±0.02^{r}	901.99±0.01^{k}	94.36±0.02^{e}
	Cooked	2.78±0.02^{c}	5.15±0.01^{l}	895.05±0.02^{n}	272.29±0.04^{h}	415.28±0.03^{q}	709.75±0.03^{d}	81.38±0.04^{b}
H	Raw	3.86±0.03^{g}	4.94±0.02^{k}	864.28±0.04^{m}	272.27±0.01^{h}	484.89±0.01^{t}	671.93±0.03^{c}	99.12±0.03^{f}
	Cooked	3.12±0.01^{e}	2.82±0.02^{d}	384.30±0.02^{f}	126.45±0.02^{b}	332.86±0.04^{i}	565.17±0.04^{a}	77.42±0.03^{a}
I	Raw	8.63±0.03^{o}	3.81±0.03^{h}	624.92±0.03^{j}	175.18±0.02^{e}	376.78±0.01^{m}	828.57±0.03^{h}	121.60±0.01^{m}
	Cooked	4.08±0.01^{h}	3.37±0.02^{f}	544.13±0.03^{i}	138.63±0.01^{d}	304.15±0.02^{f}	671.94±0.02^{c}	88.26±0.03^{c}
X	Raw	7.43±0.04^{l}	5.40±0.01^{m}	944.11±0.04^{p}	223.74±0.03^{g}	364.38±0.02^{l}	956.66±0.05^{o}	117.55±0.02^{l}
	Cooked	2.99±0.01^{d}	4.94±0.02^{k}	864.07±0.02^{l}	220.01±0.02^{f}	191.60±0.03^{a}	912.97±0.02^{m}	108.60±0.04^{h}

Values are means ± SD of triplicate determinations. Different superscripts letters in the same column indicate a statistical difference ($p < 0.05$) between the cultivars. A= NUV-109-2; B= ECAPAN 021; C= GLP-190-C; D= MAC-55; E= MAC-33; F= DOR-701; G= FEB-192; H= GLP-190-S; I= NUA-99; X= unknown

Table 3. Antinutrient contents of raw and cooked red beans (*Phaseolus vulgaris L.)* cultivars expressed as a percentage

Cultivars		Phytates %	%Red	Tannins %	%Red	Oxalates %	%Red	Saponins %	%Red
A	Raw	9.28±0.00^{hij}	33.30±0.38	2.45±0.15^{ij}	86.94±0.11	0.35±0.00^{f}	74.29±0.00	1.28±0.06^{i}	4.69± 0.03
	Cooked	6.19±0.77^{cde}		0.32±0.07^{ab}		0.09±0.00^{a}		1.22±0.00^{hi}	
B	Raw	8.51±0.77^{fghij}	43.60±0.46	0.84±0.07^{bcdef}	46.43±0.04	0.21±0.03^{cde}	28.57±0.02	1.15±0.00^{gh}	39.13±0.00
	Cooked	4.80±0.15^{bc}		0.45±0.01^{abcd}		0.15±0.01^{abcd}		0.70±0.01^{de}	
C	Raw	10.06±0.77^{j}	44.63±0.52	2.83±0.01^{j}	83.75±0.01	0.18±0.00^{bcde}	27.78±0.00	0.95±0.01^{f}	36.84±0.02
	Cooked	5.57±0.27^{bcd}		0.46±0.02^{abcd}		0.13±0.00^{abc}		0.60±0.04^{cd}	
D	Raw	8.20±0.15^{fghi}	16.95±0.15	1.73±0.03^{gh}	80.35±0.02	0.23±0.03^{e}	69.56±0.01	0.72±0.00^{e}	63.89±0.00
	Cooked	6.81±0.15^{def}		0.34±0.02^{abc}		0.07±0.00^{a}		0.26±0.01^{a}	
E	Raw	9.75±0.27^{ij}	26.97±0.21	1.17±0.17^{efg}	34.19±0.08	0.18±0.00^{bcde}	50.00±0.00	1.12±0.00^{gh}	75.00±0.01
	Cooked	7.12±0.15^{defg}		0.77±0.00^{abcdef}		0.09±0.00^{a}		0.28±0.02^{a}	
F	Raw	9.13±0.15^{hij}	47.43±0.15	4.52±0.23^{k}	96.90±0.11	0.47±0.03^{g}	72.34±0.01	4.26±0.01^{k}	78.17±0.00
	Cooked	4.80±0.15^{bc}		0.14±0.00^{a}		0.13±0.00^{abc}		0.93±0.00^{f}	
G	Raw	4.80±0.15^{bc}	40.42±0.47	2.04±0.13^{hi}	64.70±0.15	0.41±0.03^{f}	56.10±0.01	3.68±0.05^{j}	92.66±0.03
	Cooked	2.86±0.8^{a}		0.72±0.18^{abcde}		0.18±0.00^{bcde}		0.27±0.01^{a}	
H	Raw	4.80±0.15^{bc}	19.37±0.15	1.10±0.13^{defg}	81.82±0.10	0.66±0.03^{h}	84.84±0.02	0.52±0.03^{bc}	15.38±0.02
	Cooked	3.87±0.15^{ab}		0.20±0.07^{ab}		0.10±0.01^{ab}		0.44±0.01^{b}	
I	Raw	9.28±0.00^{hij}	4.96±0.13	1.40±0.27^{fgh}	75.00±0.17	0.22±0.00^{de}	31.82±0.00	1.10±0.00^{g}	2.73±0.00
	Cooked	8.82±0.27^{ghij}		0.35±0.07^{abc}		0.15±0.01^{abcd}		1.07±0.01^{g}	
X	Raw	7.89±0.27^{efgh}	13.69±0.21	1.40±0.12^{fgh}	28.57±0.16	0.67±0.01^{h}	77.61±0.01	0.46±0.00^{b}	0.00±0.00

Values are means ± SD of triplicate determinations. Different superscripts letters in the same column indicate a statistical difference ($p < 0.05$) between the cultivars. A= NUV-109-2; B= ECAPAN 021; C= GLP-190-C; D= MAC-55; E= MAC-33; F= DOR-701; G= FEB-192; H= GLP-190-S; I= NUA-99; X= unknown

Dietary fiber contents in the red bean cultivars ranged between 2.42 to 6.29 g/100g DM and 3.25 to 7.97 g/100g DM respectively for raw and cooked samples. The dietary fiber content of the investigated samples compares with the value (2.7 to 7.9%) reported by [32]. but lower than those reported for roasted Lima bean (*Phaseolus Lunatus)* seeds [33]. Fiber improves food bulk, appetite satisfaction, lowers cholesterol level and prevents constipation [19].

The ash content of the samples ranged from 3.20 to 4.80 g/100g DM and 1.93 to 3.26 g/100g DM for raw and cooked samples respectively. Cooked bean samples contained the least ash. which could be due to the leaching of salts and minerals in the cooking water. Similar reports were presented by [34,35]. Our results were lower to the 4.51 to 3.90 g/100 g DM obtained by [18] in Nigeria on treated lima beans *(Phaseolus Lunatus).*

4.2 Mineral Analysis

The mineral contents of the red bean cultivars samples are shown in table 2. Many authors reported that the consumption of beans increases the amount of several minerals in the diet [18].The raw and cooked samples contained appreciable amount of minerals with potassium and calcium the most abundant minerals. The content of all minerals evaluated (potassium. calcium. phosphorus. magnesium. sodium. iron and zinc) were significantly reduced ($p < 0.05$) with cooking. In fact. several studies have already shown that soaking combined with cooking significantly reduce mineral contents [18,36]. Moreover. the variation in levels observed between different cultivars could be explained by many factors such as genotype. origin. environment and growing conditions. which influence the quality of bean seeds [37,38].

The potassium content ranged from 671.93 to 1047.15 mg/100 g DM and from 565.17 to 912.99 mg/100 g DM for the raw and cooked samples respectively. The potassium content of the different cooked samples were higher compared to those found **(**34.78 mg/100 g DM) in Nigeria [39] on cowpea. Potassium is nutritionally important for pH regulation and the proper functioning of carbohydrate and protein metabolism [40]. For this reason. kidney beans are an excellent food to cover daily potassium requirements.

The calcium content ranged from 272.77 to 1064.35 mg/100g DM and 78.5 to 933.85 mg/100g DM for raw and cooked bean samples respectively. Calcium contents in our cooked samples were lower than 600 mg/100g DM obtained in Egypt [41] on white beans with the exception of MAC-33. DOR-701. FEB-192 and X which showed higher levels. Calcium is known as a macroelement necessary for the development of teeth. bones and the release of hormones [42]. So, our red bean cultivars samples are excellent sources of calcium for child nutrition.

The magnesium content of the cultivars ranged from 175.18 to 418.06 mg /100 g DM and 77.86 to 272.29 mg/100 g DM for raw and cooked beans sample respectively. Soaking combined with cooking decreased significantly the magnesium content in the raw samples. Our findings were lower compared to those found in West Cameroon (442.26 and 714.42 mg/100 g DM) by [43] on cultivar PB (small white grain) respectively cooked and raw, but similar to those found on cultivars GLP-190-C, MEX 142. PH 201 and GGR whose values ranged from 130.75 to 199.26 mg/100 g DM and 184.68 to 260.72 mg/100g DM respectively for cooked and raw samples in the same study in West Cameroon. Magnesium is required for bone formation which maintains the electrical potential in nerves [43]. It is important for the release and action of insulin [44].

The phosphorus content of the cultivars ranged from 337.41 to 484.89 mg/100 g DM and from 191.60 to 415.28 mg/100g DM for raw and cooked samples respectively. These different phosphorus levels in our samples were high compared to those found in Nigeria [45] on red beans (2.7 mg/100g DM). but lower than those found by [39] (638.04 mg/100 g DM) on cowpeas. In the organism, phosphorus allows the osseous fixation of calcium by decreasing its urinary excretion and enters into the mechanism of energy storage and release [39].

Sodium levels in the samples ranged from 89.91 to 133.24 mg/100 g DM and 77.42 to 122.45 mg/100g DM for raw and cooked samples respectively. Our findings revealed that cooked bean samples were lower than the 322 mg/100g DM obtained in Egypt [41] on white beans**.** Sodium is frequently ingested in food in the form of sodium chloride (cooking salt) although it is naturally present in food. Without external additives. sodium levels in beans remain low to cover recommended requirements.

The zinc content ranged from 3.81 to 7.77 mg/100g DM for raw samples and 2.10 to 5.15 mg/100g DM for cooked samples. Zinc levels in cooked samples were lower compared to those reported in cooked lentil samples [46]. [1] reported similar content (5.87 and 5.95 mg/100g DM) of zinc in bean paste (Ekuru) made in Nigeria. Our findings were lower compared to the RDA range of zinc (4 to 40 mg/day) as reported by [47] but could (if bioavailability is not affected) cover the daily requirements of 3. 8 and 13 mg/day for children. men. women and pregnant women respectively [48]. Indeed. anti-nutritional factors would inhibit intestinal absorption of zinc by forming insoluble complexes [49]. 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 [18].

Iron contents ranged from 3.23 to 8.63 mg/100 g DM and 1.89 to 4.19 mg/100g DM for raw and cooked samples respectively. The values obtained for the cooked bean samples in were lower than those obtained in Egypt [41] on white beans (4.52 mg/100g DM), but in agreement (1.88 to 3.13 mg/100g DM) with the values reported for some varieties of white and black beans in West Cameroon [43]. Iron helps in the formation of blood and in the transfer of oxygen and carbon dioxide from one tissue to another. Iron deficiency results in impaired learning ability and behavioral problems in children, and also anemia [3].

4.3 Antinutrient Analysis

Antinutrient content of the red bean cultivars samples are shown in table 3. Antinutrients are natural or synthetic plant compounds that reduce the body's ability to digest and absorb essential nutrients such as protein. vitamins and minerals. They include lectin. tannin. phytate. saponine and oxalate [50]. Their positive or negative effects seem to be associated with their concentration in the beans which depends on type of bean. as well as their interaction with other components of the diet [23]. The findings of this study show that soaking combined with cooking significantly reduced antinutrients content in red bean cultivars.

Tannin content ranged between 0.84% to 4.52% and 0.14% to 1.00% in raw and cooked samples respectively. The tannin content in the raw cultivars in this study is far lower than the 150 to 200 mg/100g of safe level reported by [51]. The values obtained in our study. were very lower compared to the 66mg/100g DM reported by [52] in *Dioscorea bulbilas* in southeast of Ivory Coast. Tannin-protein complexes are insoluble and this decreases protein digestibility by inhibiting the activities of digestive enzymes [1]. Tannin content in our samples was below the toxicity limit of 560 mg/day [53].

Phytate content ranged from 4.80% to 10.06% and 2.86% to 8.82% in raw and cooked samples respectively. These values were higher than the values of 2.42% and 1.09% found by [54] in Rwanda respectively on raw climbing bean meal and after soaking and cooking. High levels of phytates in human nutrition are toxic and limit the bioavailability of calcium. magnesium. iron and phosphorus by the formation of insoluble compounds with these minerals [52]. The mean daily intake of phytate is estimated to be 2000-2600 mg for vegetarian diets as well as diets of inhabitants of rural areas in developing countries. and 150-1400 mg for mixed diets. The phytate level of these samples is higher than the acceptable content for mixed diets. but within the mean daily intake of phytate. hence will have a lesser binding effect on some minerals such as Ca. Mg. Fe and Zinc [55]. The reduction of phytates in the cooked samples can be explained by their elimination during soaking by water solubility and on the other hand by the activation of the natural endogenous phytase in the legumes which degraded the phytates and thus facilitated their diffusion in the soaking water [56].

Total oxalate content ranged from 0.18% to 0.67% and 0.07% to 0.18% in raw and cooked samples respectively. The values were similar to the range (0.28 to 0.65mg/100g) reported by [57] for processed (blanched. microwaved. roasted or boiled) and raw cocoyam cormels. The author asserted that boiling causes considerable cell rupture that facilitates the leakage of soluble oxalates into the cooking water. This assertion was proven true in the present study in combination of soaking with cooking. Total oxalate levels in our samples were well below the toxicity limit of 2 to 5 g/day [53].

Saponin content ranged from 0.46% to 4.26% and 0.26% to 1.22% in raw and cooked samples respectively. These values were higher than the values of 0.05% found by [36] in Nigeria on raw and cooked beans respectively. The reduction in saponin contents in cooked samples compared to raw samples could be partly attributed to the thermo-sensitivity of saponins from the bean seed coat to the bioconversion of aglycone into other bioactive molecules or to leaching due to the diffusion of saponins in the soaking medium [58]. Saponins are known for their foaming properties in aqueous solution. astringent taste and haemolytic activity on red blood cells [43].

4. CONCLUSION

The nutritional and antinutritional characteristcs of ten red bean cultivars (*phaseolus vulgaris* L.) from Cameroon were successfully evaluated. The findings revealed that the both raw and cooked bean samples are rich in nutrients (carbohydrate. ash. protein. fiber and minerals). However. they are low in fat which is an advantage as this will reduce the risk of heart attack and metabolic diseases. Soaking combined with cooking were effective in reducing the levels of the antinutrients evaluated. thereby improving the nutritional value of the red bean seeds. These may be exploited in food formulation drives and in management of macro and micronutrients malnutrition.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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