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Quality of White Bean Seeds (*Phaseolus vulgaris* L.) As Affected by Different Treatments

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Abstract: Common beans (*Phaseolus vulgaris* L.) are a good source of protein, vitamins, dietary fiber and minerals. As beans are never eaten raw, the effect of soaking, cooking, soaking-cooking, microwaving cooking on chemical composition, functional properties and mineral contents of white bean seeds (Nebraska variety) were studied. Crude protein content ranged from 22.55 to 64.19 g/100g dry weight basis in the studied samples. Raw dry bean (RB) was the highest in ash (4.19) and total carbohydrates (53.83 g/100 g dry weight). Water and oil absorption capacity are the two functional properties studied in white beans seeds samples. The amount of water absorption capacity ranged from 264.34 to 343.77, whereas range for oil absorption capacity is in between 249.93 and 361.80 g/100g dry weight of the samples used in current study. Minerals content *i.e*. Zn, Fe, Ca, K, Na, Mg, Mn, P and Cu were studied. Results indicated that raw white beans seeds was the highest sample in K, Mn and Fe (1604.00, 15.78 and 5.78), while SSB was the highest in Mg and Zn (600.00 and 5.12 mg/100 g dry weight). Ca, Na, P had the highest concentration in CSSB, MNSB, CSB samples with values 1000.00, 819.00 and 162.50 mg/100 g dry weight, respectively. There were significant ($p<0.05$) differences between the potassium, calcium, sodium, magnesium, manganese, iron, phosphorus and zinc concentration of the white bean samples, except between copper concentration.

Key words: Cooking · Functional properties · Microwaving · Minerals · *Phaseolus vulgaris* · Soaking

INTRODUCTION

Dry beans occupy an important place in human nutrition, especially among the low - income groups of people in developing countries. They are a good source of protein (significantly higher than that of cereals), dietary fiber, starch [1], minerals and vitamins [2]. They are a staple food and low - cost source of protein in developing countries where protein energy malnutrition (PEM) is prevalent [3]. The world production of dry beans was 23.2 million metric tons (MT) in 2010, which represented an increase of almost 70% as compared to that in 1980. From 1980 to 2000, dry production increased by 3.9 million MT; however, a significantly higher increase (5.6 million MT) was reported in only the 10-year period from 2000 to 2010 [4]. The characteristics that make beans a good food value are: health, wellness and environmental sustainability. It is noteworthy that consumers are increasingly selecting healthy and balanced diets proportionally higher in plant- based foods. Legumes have significant nutritional and health advantages for consumers since they are high in protein and dietary fiber and very low in fat [5].

Recently, heightened consumer awareness has led to the promotion of less saturated fat, cholesterol, sugar and salt in the diet and the preference for complex carbohydrates such as fiber. No single food outside of the context of the total diet should be recommended exclusively; however, dry beans can be promoted as a healthy food, being nutrient dense and an excellent source of dietary fiber. The inclusion of dry beans and other legumes in the daily diet has many beneficial effects in controlling and preventing various metabolic diseases such as diabetes mellitus, coronary heart disease and colon cancer [6, 7]. In African diets, legumes are the major contributors of protein and calories for economic and cultural reasons [8]. However, their role appears to be limited because of several factors including low protein

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and starch digestibility [9], poor mineral bioavailability [10] and high antinutrtional factors. Traditional treatments such as soaking, cooking, germinating and fermenting have been used to improve nutritional quality of the legumes, the dry beans [11, 12]. Soaking is an integral part of bean processing. There is a relationship between bean structure and water absorption during the soaking process. Bean volume increases with soaking time due to seed coat softening and cotyledonary swelling. Water uptake and volume of beans increases directly with soak time and accelerates at higher soak temperatures. Increased bean damage occurred in beans soaked and processed in water with less than 50 ppm calcium. Soaked water calcium had a great effect on the processed bean firmness than did brine calcium. Legume seeds absorbed 60% and a maximum value of 95% water after 2 h and 24 h of soaking, respectively. Soaking process reduced all macro elements (e.g. K, Ca, Mg and P) and microelements (e.g. Mn, Mo, Zn, Cu and Fe) except Na during soaking in sodium bicarbonate solution [13].

Soaking can reduce the level of total sugars, α-galactosides, minerals, phytic acid and proteolytic enzyme inhibitors, which can be partly or totally solublized and eliminated with the discarded soaking solution. Cooking is probably the oldest treatment for making legumes edible. Usually it includes a previous soaking of the seeds and subsequent cooking in boiling water until they become completely soft. Addition of mineral salts to the soaking and/or cooking media can produce a reduction of the cooking time [14, 15]. In general cooking produce denaturalization of proteins and their diffusion to the liquid phase [16, 17, 18]. Beans are soaked to facilitate shorter cooking time. Soaking media includes water, salt solution and alkali. Generally, soaking is a time consuming process and it can be shorten by increasing the soaking medium to increase the water inhibition rate. Generally, the soaking time is 10 to 18 h at room temperature. Soaking beans with salt solution, discarding the soaking solution and cooking with fresh water is the recommended cooking method to preserve cooked bean flavor. Beans soaked in the salt solution and cooked with fresh water resulted in higher values of protein quality in comparison to beans soaked and cooked in the same salt solution [19, 20].

Cooking is the oldest method of bean processing. Cooking improves the nutritive value of the protein in legumes. It makes the beans edible by making them tender and aids in flavor development. For home cooking, the raw and washed beans are soaked in water for 12 to 16 hours (overnight). Such procedure is based only on everyday experience, as to its effect on cooking time [21]. During hydration, however, grain respiration and metabolism intensify and may provoke nutrient loss through dissolution. Thus, the water used for soaking must be re-used for bean preparation. Discarding the soaking water is sometimes done in home cooking [22]. Traditional legume processing and cooking methods have been improving to enhance flavor, nutritive value and consumer acceptance. Cooking is known to be fundamental for bean consumption, as it increases digestibility, inactivates antinutritional factors or antinutrients, increases nutrient biological value and confers the sensorial quality that consumers demand to improve acceptance [23]. Abusin *et al*. [24] studied the chemical composition of cooked and uncooked white bean seeds and they reported that: the moisture content of white bean cultivars was found to be 3.66% for Giza 3 and 3.41% for RO21. Cooking caused a significant increase in moisture content for both cultivars. Fat content was found to be 2.28% and 2.13% for Giza 3 and RO21, respectively. The ash content was found to be 4.90% and 4.60% for Giza 3 and RO21. Cooking caused a significant reduction in ash content for white bean cultivars. Cooking caused a significant reduction in fat and ash content. For white bean samples fiber content was 6.57% for Giza3 and 7.44% for RO21 and after cooking it was found to be 7.13% for Giza 3 and 8.53% for RO21. Onwuliri and Obu [25] reported that cooking reduce fiber content of white bean which disagree with that results. This variation may be due to differences between cultivars as well as the growing conditions. The protein content was 21.49% for Giza 3 and 19.83% for RO21. After cooking the protein content was found to be 21.32% for Giza 3 and 18.99% for RO21. In general cooking significantly ($P<0.05$) reduced the protein content of white bean. The reduction in protein content could be attributed to partial removal of certain amino acids and some other nitrogenous compounds as a result of heating [26, 27].

The human body needs about twenty different minerals in order to function properly [28]. These elements can be classified into macro and microminerals. Macro minerals are needed in amounts higher than 100 mg/day and include calcium (Ca), phosphorus (P), magnesium (Mg), sulfur (S), sodium (Na), chloride (Cl) and potassium (K). Microminerals (needed in amounts lower than 100 mg/day) include elements such as iron (Fe), zinc (Zn), iodine (I), selenium (Se), manganese (Mn), chromium (Cr), copper (Cu), molybdenum (Mo), fluorine (F), boron (B), cobalt (Co), silicon (Si), aluminum (Al), arsenic (Ar), tin (Sn), lithium (Li) and nickel (Ni) [29]. Nestares *et al*. [30]

studied the values for ash, calcium, phosphorus and magnesium content in the raw and processed beans diets and also the percentage lost due to processing. Raw bean contained 1.65 g of calcium, 3.85 g of phosphorus and 1.62 g of magnesium/kg of sample. Soaking followed by cooking decreased the mineral content by 2.5- 16% for calcium, by 9-16% for phosphorus and by 18-27% for magnesium. In general, mineral loss fell as the pH of the soaking solution increased.

The aim of this work was to study the effect of some conventional treatments (soaking and different cooking methods) on chemical composition, functional properties and minerals of white beans seeds.

MATERIALS AND METHODS

Material: Dried white beans (*Phaseolus vulgaris* L.) variety Nebraska (10 kilogram) was purchased from Agricultural Research Center - Giza - Egypt during the summer season 2012.

Bean Samples Analyzed: Beans were prepared in six different ways. The details of sample preparation are given below.

Raw Dry Beans (RB): The samples were ground for 3 min in laboratory mill.

Soaked Beans (SB): Beans soaked in tap water overnight at room temperature (300 ml of water were added to 100g of bean seeds; soaking took place for 18h at 20°C); the soaked seeds were drained and dried in an electrical oven at 50°C for 24 hours then ground for 3 min in laboratory mill.

Soaked-S Beans (SSB): Beans soaked overnight in a solution of baking soda in tap water at room temperature, (300 ml of water containing 5.0 g of baking soda were added to 100g of bean seeds, soaking took place for 18h at 20°C), the soaked seeds were drained and then treated in the same way as SB.

Cooked Soaked Beans (CSB): Beans soaked in tap water overnight at room temperature (300 ml of water were added to 100g of bean seeds, soaking took place 18h at 20°C) then drained and dried on a paper towel and consequently cooked in fresh tap water (volume ratio beans to water being 1-6) boiling in a covered pot (98-100°C) until they became suitable for consumption (approx. 40 min). Cooked seeds were drained and treated in the same way as SB.

Microwaved Soaked Beans (MSB): Beans soaked in tap water overnight at room temperature (300 ml of water were added to 100 g of bean seeds, soaking took place 18 h at 20°C) then drained and dried on a paper towel and consequently cooked with fresh tap water (volume ratio beans to water being 1-6) in microwave oven at 2450 MH until they became suitable for consumption (approx. 40 min). Microwaved cooked seeds were drained and treated in the same way as SB.

Cooked Soaked-S Beans (CSSB): Beans soaked in a solution of baking soda in tap water overnight at room temperature (300 ml of water containing 5.0 g of baking soda were added to 100g of bean seeds and soaked for 18h at 20°C) then drained and dried on a paper towel and consequently cooked in fresh tap water (volume ratio beans to water being 1-6) boiling in a covered pot (98-100°C) until they became suitable for consumption (approx. 40 min). Cooked seeds were drained and treated in the same way as SB.

Microwaved Soaked-S Beans (MSSB): Beans soaked in a solution of baking soda in tap water overnight at room temperature (300 ml of water containing 5.0 g of baking soda were added to 100g of bean seeds and soaked for 18h at 20°C) then drained and dried on a paper towel and consequently cooked with fresh tap water (volume ratio beans to water being 1-6) in microwave oven at 2450 MH until they became suitable for consumption (approx. 40 min). Microwaved cooked seeds were drained and treated in the same way as SB.

Cooked Nonsoaked Beans (CNSB): Beans directly cooked in boiling water until they became suitable to consumption. Nonsoaked beans (50g) were cooked in 400 ml of tap water boiling in a covered pot (98-100°C) until they became suitable for consumption (approx. 2h). Cooked seeds were drained and treated in the same way as SB.

Microwaved Nonsoaked Beans (MNSB): Nonsoaked beans directly cooked with fresh tap water (volume ratio beans to water being 1-6) in microwave oven at 2450 MH until they became suitable for consumption (approx. 2h). Microwaved cooked seeds were drained and treated in the same way as SB.

MATERIALS AND METHODS

Physical Characteristics of Raw White Bean Seeds: Weight, Volume and Density: Seed weight (g) and volume (ml) were determined according to method described by Phirke *et al*. [31]. Seed density was calculated from the values obtained for weight and volume of seeds.

Swelling Capacity: 50 seeds of raw seeds were weighted followed by cooking in boiling water for 20 min. Seeds were drained and reweighed and their swelling capacity was determined by method as described by Akinyele *et al*. [32].

Water Absorption: Water absorption of raw seeds was determined by soaking 10 g seed in water at a ratio of 1:5 by following the method of Sefa Dedeh and Stanley [33].

Chemical Composition: Moisture, crude protein, crude oil, crude fiber and ash were determined as described in the AOAC Methods [34], while the carbohydrate content was calculated by difference according to Pellet and Sossy [35]. Triplicate determinations were carried out for each sample and the means were reported.

Functional Properties of White Bean Seeds Flour: Water and Oil Absorption Capacity: One gram of sample was mixed with 10ml refined corn oil or distilled water in a weighted 20mL centrifuge tube. The slurry was agitated on a Vortex mixer for 2 minutes, allowed to stand at 28°C for 30 minutes and then centrifuged at 500×g for 30 minutes.

The clear supernatant was decanted and discarded. The adhering drops of oil or water were removed and the tube was weighed. The weight of oil or water absorbed by 1g of flour of protein was calculated and expressed as oil or water absorption capacity [36, 37].

Determination of Minerals: Minerales (Ca, Fe, Cu, Zn, Mg and Mn) were analyzed by GBC Atomic Absorption 906 A.A. Na, K were determined by a flame photometer corning 400 and P was determined by spectrophotometer [38] after wet ashing by method described in AOAC [34].

Statistical Analysis: The data collected were analyzed with analysis of variance (ANOVA) Procedures using the MSTAT-C Statistical Software Package [39]. Differences between means were compared by LSD at 5% level of significant [40].

RESULTS AND DISCUSSION

Physical Characteristics of Raw White Bean Seeds: Physical parameters are important for the quality of white bean seeds and acceptability by the consumers. The seeds volumes were 40.50 ml and 100 seeds weight were 49.88 g for white beans seeds as depicted in Table 1. Water absorption, swelling capacity of the seeds were 41.19 (g/100g) and 75.35 (g/100g), respectively. Apparent seed density of white beans seeds was found to 1.23 (g/ml). It is apparent from results that seed size influence the physical characteristics particularly the water absorption capacity of legume. These results are in line with the findings of Deshpande´ *et al*. [41].

Chemical Composition and Functional Properties of Soaked and Cooked White Bean Seeds Flour: The raw bean contained the highest ash and carbohydrate content when compared with other treatments ($p<0.05$). The moisture content of white bean samples was ranged from 9.23 to 72.58%. Soaking and cooking caused a significant increase in moisture content for the treated samples (Fig.1) as compared with raw white bean seeds flour.

The processes applied in this research on the Nebraska dry bean variety and the changes occurred in the proximate composition was shown in Table 2. The CSSB (64.19) and CSB (60.15 g/100 g dry weight) samples were effectively increased the protein content as a result of soaking when compared with the other samples. Crude oil content of white bean samples was ranged from 3.20 (RB) to 6.17 (SSB) g/100 g dry weight. The fiber content was 10.76 for RB, after soaking, cooking it was found to be 6.42; 6.37; 7.08; 6.15 g/100 g dry weigh for SB; SSB; CSSB and CSB. Soaking, cooking caused a significant ($p<0.05$) reduction in ash and carbohydrates content for white bean samples. As could be noticed in Table 2, cooking the sample after soaking in sodium bicarbonate solution (CSSB) causes more decrease in total carbohydrate content 21.94 than that of the sample (CSB) soaked in distilled water 27.45, as compared with untreated (RB) white bean 59.30 g/100 g dry weight. Ku *et al*. [42] noted that soaking in the 0.5% sodium bicarbonate solution might increase softening of the testa and cotyledons that could increase the sugars extraction. In this research, microwave cooking had a significant ($p<0.05$) effect on the carbohydrate decreasing. The decrease in carbohydrates content was high in the microwave-cooking sample that was soaked in sodium bicarbonate solution (Table 2). Our results are in agreement with those obtained by Abusin *et al*. [24],

Table 1: Physical characteristics of white bean seeds.

Sample	Weight 100 seeds	Volume 100 seeds	Seed density	Swelling capacity	Water absorption
White bean	49.88 (g)	40.50 (ml)	1.23 (g/ml)	75.35 (g/100g)	41.19 (g/100g)

Table 2: Chemical composition of soaked and cooked white beans seeds flour (g/100g dry weight).*

Sample	Ash	Crude oil	Crude protein	Crude fiber	Total carbohydrates
RB	4.19^{A}	3.20^{H}	22.55^{I}	10.76^{B}	59.30^{A}
SB	3.38^{C}	5.38^{B}	41.51^{F}	6.42^{G}	43.31^{B}
SSB	3.66^{B}	6.17^{A}	40.82^{H}	6.37^{H}	42.98^{C}
CSB	2.75^{G}	3.50^{G}	60.15^{B}	6.15^{I}	27.45^{H}
MSB	2.71^{H}	5.23^{C}	47.23^{E}	11.36^{A}	33.47^{E}
CSSB	2.85^{F}	3.94^{F}	64.19^{A}	7.08^{E}	21.94^{I}
MSSB	3.01^{E}	4.67^{D}	52.90^{C}	7.04^{F}	32.38^{F}
CNSB	2.57^{I}	4.61^{E}	53.88^{D}	9.66^{D}	29.28^{G}
MNSB	3.27^{D}	4.61^{E}	40.89^{G}	9.93^{C}	41.30^{D}

*Means having different superscripts within the column are significantly different at $p < 0.05$.

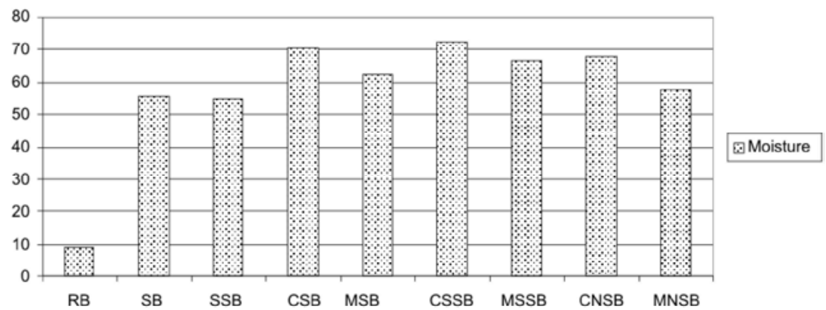

Fig. 1: Moisture content (%) of soaked and cooked white bean seeds flour.

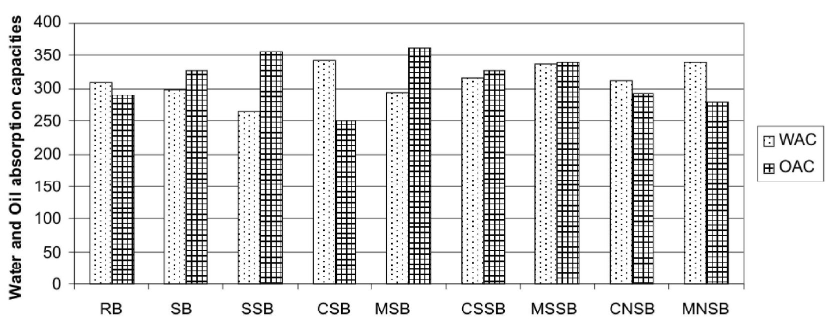

Fig. 2: Water absorption capacity (WAC) and oil absorption capacity (OAC) of soaked and cooked white bean seeds flour.

Onwuliri and Obu [25], Monica and Theresia [26] and Clawson and Taylor [27], who reported that, there is a significant reduction in some parameters composition (except moisture) as a result of soaking and cooking.

Water and oil absorption capacities are crucial factors in food functionality, as they influence emulsion and other properties. These properties of white beans samples are shown in Fig. 2. Water absorption capacity (WAC) of the nine seed flour samples ranged between 264.34 and 343.77 g/ 100 g dry weight. CSB sample showed the highest water absorption (343.77) as compared with other samples. There was no difference in water absorption capacity of MSSB (337.17), MNSB (338.07); RB (310.32) and CNSB (310.77 g/100 g dry weight) seed flours, respectively. Lower water absorption of sample could be due to the low availability of polar amino acids which have been shown to be primary sites for water interaction of proteins [43].

Oil absorption capacity is of great importance from an industrial viewpoint, since it reflects the emulsifying capacity (OAC), a highly desirable characteristic in products such as mayonnaise [44]. MSB sample exhibited

Table 3: The mineral content of soaked and cooked samples (mg/100 g dry weight of seed flour).

Sample	Fe	Cu	Zn	Mn	P	K	Na	Mg	Ca	Na/K	Ca/P
RB	5.78^{A}	1.62$^{N.S}$	4.74^{B}	15.78^{A}	120.00^{F}	1604.00^{A}	493.00^{D}	480.00^{B}	800.00^{B}	0.31	6.67
SB	4.74^{D}	1.80$^{N.S}$	3.49^{F}	9.52^{E}	147.50^{B}	767.00^{E}	601.00^{B}	360.00^{C}	600.00^{C}	0.78	4.07
SSB	4.68^{E}	1.59$^{N.S}$	5.12^{A}	9.28^{G}	110.00^{G}	709.00^{G}	309.00^{I}	600.00^{A}	400.00^{D}	0.44	3.64
CSB	4.52^{F}	1.27$^{N.S}$	3.82^{E}	10.21^{B}	162.50^{A}	912.00^{C}	322.00^{H}	360.00^{C}	600.00^{C}	0.35	3.69
MSB	4.48^{G}	1.46$^{N.S}$	3.89^{C}	9.82^{D}	127.50^{E}	826.00^{D}	342.00^{G}	360.00^{C}	600.00^{C}	0.41	4.71
CSSB	5.12^{C}	1.18$^{N.S}$	3.85^{D}	8.75^{H}	145.00^{C}	645.00^{H}	501.00^{C}	360.00^{C}	1000.00^{A}	0.78	6.90
MSSB	5.35^{B}	1.05$^{N.S}$	2.92^{G}	5.46^{I}	102.50^{H}	501.00^{I}	360.00^{E}	120.00^{E}	1000.00^{A}	0.72	9.76
CNSB	3.86^{I}	1.31$^{N.S}$	2.62^{I}	9.31^{F}	130.00^{D}	713.00^{F}	344.00^{F}	240.00^{D}	800.00^{B}	0.48	6.15
MNSB	3.98^{H}	1.46$^{N.S}$	2.69^{H}	10.02^{C}	147.50^{B}	982.00^{B}	819.00^{A}	600.00^{A}	600.00^{C}	0.83	4.07

Means having different superscripts within the column are significantly different at $p < 0.05$.

higher oil absorption (361.80) than those of the other samples (Fig. 2), suggesting the presence of more hydrophobic amino acids in MSB. The existence of several non polar side chains may bind the hydrocarbon chains of fats, thereby resulting in higher absorption of oil [45]. The OAC of SB flour (327.42) was not different from the CSSB flour (327.50) but CSB flour (249.93 g/100 g dry weight) was different and smaller than the other seed flours. The high value of OAC of white bean seed flour shows that it increases the mouth feel when used in food preparations, such as sausages, meat replacers and extenders, doughnuts, baked goods and soups.

Mineral Content of Soaked and Cooked White Bean Seeds Flour: The mineral content in mg/100 g of the soaked and cooked white beans seed flours are presented in Table 3. Analysis of variance indicated that there was a significant varietal effect on Ca, Na, P, Fe, K, Mg, Mn and Zn contents. The abundant minerals in the studied samples were potassium and calcium with values ranging from 501.00 - 1604.00 and 400.00 - 1000.00 mg/100 g, respectively, followed by sodium (309.00 - 819.00) and magnesium (120.00 - 600.00 mg/100 g). Phosphorus varied from 102.50 to 162.50, manganese from 5.46 to 15.78, iron from 3.86 to 5.78 and zinc from 2.62 to 5.12 mg/100 g. According to the data in Table 3 there was no significant effect on copper content in all studied samples and it ranged from 1.05 to 1.80 mg/100 g. The largest mineral losses in quantitative terms was magnesium, although the quantity retained by the seed is still very high and so the bean that is processed in this way may still be considered an excellent source of magnesium. The obtained data showed that, manganese, iron were most retained within the soaked, cooked seeds and the amount lost in the basic solution was insignificant (Table 3).

Minerals content of legumes showed significant reduction (18.99-39.50%) during soaking and cooking due to leaching of minerals into the used water. Cooking result in separation of some bean cells rather than breaking which in turn release the cell contents (protein, minerals, sugars etc.) to the surrounding media and consequently caused reduction in the nutrients of bean [46, 47]. The minerals contents of the raw bean variety examined in this study were within the ranges reported by other researchers [48, 49]. The ratios of sodium to potassium (Na/K) and calcium to phosphorus (Ca/P) are also shown in Table 3. The Na/K ratio in the body is of great concern for prevention of high blood pressure. Na/K ratio less than one is recommended. Hence, most of these samples would probably reduce high blood pressure disease because they had Na/K less than one. Modern diets which are rich in animal proteins and phosphorus may promote the loss of calcium in the urine [50]. This has led to the concept of the Ca/P ratio. If the Ca/P ratio is low (low calcium, high phosphorus intake) more than the normal amount of calcium may be loss in the urine, decreasing the calcium level in bones. Food is considered "good" if the ratio is above one and "poor" if the ratio is less than 0.5 [51]. The Ca/P ratio in the present study ranged between 3.64 in (SSB) to 9.76 in (MSSB) indicating they would serve as good sources of minerals for bone formation.

CONCLUSIONS

Processing, cooking and pretreatment of white beans resulted in significantly different water, K, Ca, Na and Mg contents. From the results obtained in this study, both soaking and cooking had significant effect on the chemical composition of beans. All samples showed a significant increase in their moisture contents as a result of soaking and cooking. Minerals contents of beans samples showed a significant reduction during the process of cooking due to leaching of minerals into cooking water.

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