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EFFECTS OF MINERAL COMPOSITION ON COOKING QUALITY AND RELATIONSHIP BETWEEN COOKING AND PHYSICOCHEMICAL PROPERTIES OF ETHIOPIAN BEAN (*PHASEOLUS VULGARIS* L.) VARIETIES

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Abstract: The effects of mineral composition on the cooking quality (texture and cooking time) of bean (*Phaseolus vulgaris* L.) varieties were investigated. A positive correlation was found between cooking time and mineral (calcium, magnesium, potassium) composition. Cooking time was found to decrease with an increase in water hydration capacity. Hardness of cooked beans, measured using a texture analyzer, was negatively correlated with both seed mass and water hydration capacity. Hardness also correlated positively with unhydrated seeds and Ca, Mg and K cations in bean seed. Ca, Mg and K are the principal cations which prevent water permeation into bean and have effects on cooking qualities of the tested bean samples. They have revealed a direct relationship with hardness. These cations of the bean depend on the soil composition where the beans are grown. Hence, for a given variety, soil composition determines mineral composition of bean which in turn determines important characteristics like cooking time and hardness. It was also indicated that haricot bean seed mass (g/100seeds) had a significant ($P< 0.05$) effect on swelling capacity and cooking quality of beans. Beans with lower values in seed mass exhibited higher swelling and water hydration capacity, shorter cooking times and softer texture after cooking. Among the tested samples, Awash, Mexican Roba and Tabor varieties exhibit good grain quality due to their cooking characteristic, physicochemical properties and cooked bean texture.

Key words: Cooking quality, Cooking time, Ethiopia, Haricot bean, Mineral composition, *Phaseolus vulgaris*, Texture

Introduction

Food legumes are potential sources of several important nutrients. Legumes, considered as underprivileged man's meat, are generally good sources of protein, dietary fiber and starch (Perla *et. al.*, 2003). Amongst the commonly consumed food legumes, haricot beans (*Phaseolus vulgaris* L.) occupy an important place in human nutrition in Ethiopia. They not only add to variety in the human diet but also serve as an economical source of supplementary protein, especially in the East and Great

Lakes Regions of Africa (Doughty and Walker, 1982). Ethiopia has been exporting haricot bean over 68 countries for more than 40 years. The major producing area is the central rift valley of Ethiopia, where the dominant part of the exported haricot bean is usually produced (Dawit and Demelash, 2003).

A major drawback to the utilization of beans is their decreased cookabilty after storage at high temperatures and humidity (Jackson and Varriano-Marston, 1981). Increased cooking times for stored beans have been related to the development of hard shell, whereby seeds fail to absorb water within a reasonable cooking time. The two types of hard shell reported were the hard shell related to seed coat impermeability and hard shell related to cotyledon impermeability (Morris *et. al.*, 1950). Calcium, magnesium and potassium are the principal mineral component present in bean seed. In order to increase the haricot bean production and consumption, one of the approaches is to develop varieties with higher yields and lower cooking time than the existing ones. With this objective, breeding trials for growth potential of new varieties of haricot bean have been carried out by plant breeders in Ethiopian agriculture research centers. New cultivars of *P. vulgaris* are continually being developed and released from the research centers. The economic value of a new cultivar depends on its yield, rate of maturity, its resistance to disease, seed size, color, nutritional quality, cooking time, and the flavor and texture of the cooked food. The criteria for selection have always been resistance to disease, yields and rate of maturation, but hardly ever nutritive/cooking quality.

Cooking time varies regionally and is a criterion for consumer acceptance and more prominent and paramount where firewood is the main fuel source in Africa (Sperling *et. al.,* 1996). Cooking quality (cooking time and texture) is important in determining the energy cost for preparation of meals. Thus, it is important to report the cooking quality for industrial, environmental, market and household advantages in reducing drudgery as well as to diminish environmental degradation through less fuel and energy consumption. A study of the effect of mineral composition on cooking quality and relationship between cooking and physicochemical properties of bean varieties would therefore be of great interest to Ethiopia. The knowledge provided would also help those who are engaged in varietal selection, agro-processing activities, bean exporters or importers and consumers.

The purpose of this study was to investigate the effect of mineral composition on cooking quality and define the relationship between texture of cooked beans with cooking time and mineral composition. Moreover, physicochemical properties of haricot bean varieties grown in Ethiopia were compared to those observed in haricot beans grown in other areas of the world. Such information may be useful to bean exporters, processors and breeders in their screening of new potential cultivars.

Materials and Methods

The seeds of eight *Phaseolus vulgaris* L. varieties were used in this study and were grown at the Nazareth Agricultural Research Centre. All varieties were released from research centres of Alemaya, Awassa, Jimma and Nazareth. Normal agronomic practices required for haricot bean crops were followed. Each variety of test bean samples was cleaned and sorted out by size, colour and appearance, and absence of foreign, broken, damaged or abnormal odours and living or dead insects before testing commenced. The haricot bean seeds were sealed and placed in plastic bags and stored at 4 °C before use. All chemicals and reagents used were either analytical or reagent grade.

Physicochemical properties

Unprocessed seeds of the given varieties were analyzed for seed mass, bulk density, volume, hydration capacity, hydration index, swelling capacity and swelling index according to Bishnoi and Khetarpaul (1993), Williams *et. al.,* (1983), and Youssef (1978). Cooking quality, which includes cooking time of bean varieties and their texture, were analyzed by methods suggested by Jackson and Varriano-Marston (1981) and Wang *et. al.*, (2003).

Hundred seed mass

One hundred seed mass was determined by counting 100 seeds using an electronic seed counter and weighing. Results were expressed as the mean of duplicate determinations.

Density

Seeds (100 g) of the sample after accurately weighing were transferred to a measuring cylinder, where 100 ml distilled water at 20 °C is added. Seed volume (ml/100 g seeds) was obtained after subtracting 100 ml from the total volume (ml). Volume increase was measured immediately, so that swelling character was not a problem. The density of bean seeds was calculated and recorded as g/ml (Bishnoi and Khetarpaul, 1993).

Hydration and swelling coefficient

The hydration coefficient of raw bean seeds soaked in distilled water for 24 h was calculated as the percentage increase in mass of beans. The volume of raw bean seeds before and after soaking in distilled water for 24 h was estimated by determination of displaced water (Youssef, 1978). Swelling coefficient was calculated as a percentage of the ratio of volume of bean seeds before soaking to after soaking.

Hydration, swelling capacity and indices

About 100 g of seeds were counted and transferred to measuring cylinder and 100 ml water added. The cylinders were covered with aluminum foil and left overnight at room temperature. The next day all seeds were drained, superfluous water removed with filter paper and swollen seeds reweighed. Hydration capacity expressed as hydration capacity per seed was determined by dividing the mass gained by the seed by the number of seeds present in sample.

Seeds in a mass of 100 g were counted, their volume noted and soaked overnight. The volume of the soaked seeds was noted in a graduated cylinder. Swelling capacity per seed was calculated as the volume gained by the seeds divided by the number of seeds (Bishnoi and Khetarpaul, 1993).

The swelling index can be calculated as the ratio of swelling capacity per seed to volume of one seed (ml). Hydration index then can be calculated using the formula (Bishnoi and Khetarpaul, 1993) as the ratio of the average hydration capacity per seed and the mass of one seed.

Water absorption studies

Dry bean samples were soaked in distilled water at 20 °C. The seeds were then removed at regular intervals during soaking, dried by blotting with filter papers and weighed. The water absorbed by the seeds was calculated as percent of the fraction of the mass gained by seeds on soaking to the mass before soaking.

Mineral composition analyses in beans

The minerals were analyzed from triple acid digested samples using the suggested method of Isaac and Johnson (1975), by atomic absorption spectrophotometer (Hitachi, Model Z-8230, Japan). Phosphorus content was determined colorimetrically (Dickman and Bray, 1940) using UV/Visible spectrophotometer (Model 6405, Jenway Ltd. UK, 1999).

Cooking time

The apparatus used for determining the cooking time was a Mattson cooking device (Mattson, 1946), modified by Jackson and Varriano-Marston (1981). The apparatus has a cooking rack with 25 hollow plungers and 25 cylindrical holes of the cooker. The piercing tip of 82 g rod was in contact with surface of the bean placed in the hole. A bean sample (about 50 g) was soaked in deionized water for 24 h at room temperature before cooking.

Soaked beans were then positioned into each of the 25 saddles of the rack so that the tip of each plunger was in contact with the surface of the bean. The rack is then placed into a 2l metal beaker containing 1.5l of boiling water. When a bean became sufficiently tender, the plunger penetrates the "cooked" bean and dropped a short distance through the hole in the saddle. The top of the dropped plunger was approximately 4 cm lower than the tops of the other plungers that had not yet dropped, making it easy to determine when a plunger had penetrated its corresponding bean (Jackson and Varriano-Marston, 1981; Wang *et. al.,* 2003). Cooking time was estimated on the basis of the time required to cook 50% of sample (Morris, 1963).

Texture measurement of cooked beans

The texture of cooked beans was measured with a LLOYDЖ, TA 500, 1998, England, texture analyzer (Intro enterprise Co. LTD). The category of test used for texture (hardness) was general-purpose compression set up with compress to limit test type. A bean sample (60 g) was soaked in 300 ml of distilled water at room temperature for 24 h. After draining the water, the sample was transferred into a perforated container and cooked in a boiling water-bath for its previously determined cooking time (described above). The cooked beans were then drained for 1 min and measurements were performed within 10 min. Only beans with no sign of skin breakage after being cooked in a boiling water-bath for its previously determined cooking time were selected for testing.

The test method defines compress a specimen to 75% of its height (thickness). Approximately 20 g of cooked beans were loaded on the specimen holder of the LLOYDЖ (Fig. 1) in a single layer and compressed with a compressing plate to the deflection at 75% of the specimen height using slightly modified method of Wang *et al.*, (2003). The load cell used for hardness measurement was 500 N. Furthermore, the maximum compression force was measured and recorded at a crosshead speed of 50 mm min^{-1}. This is expressed as the maximum compression force per gram of cooked sample (N force g^{-1} cooked sample). Values were reported as the means of triplicate determinations.

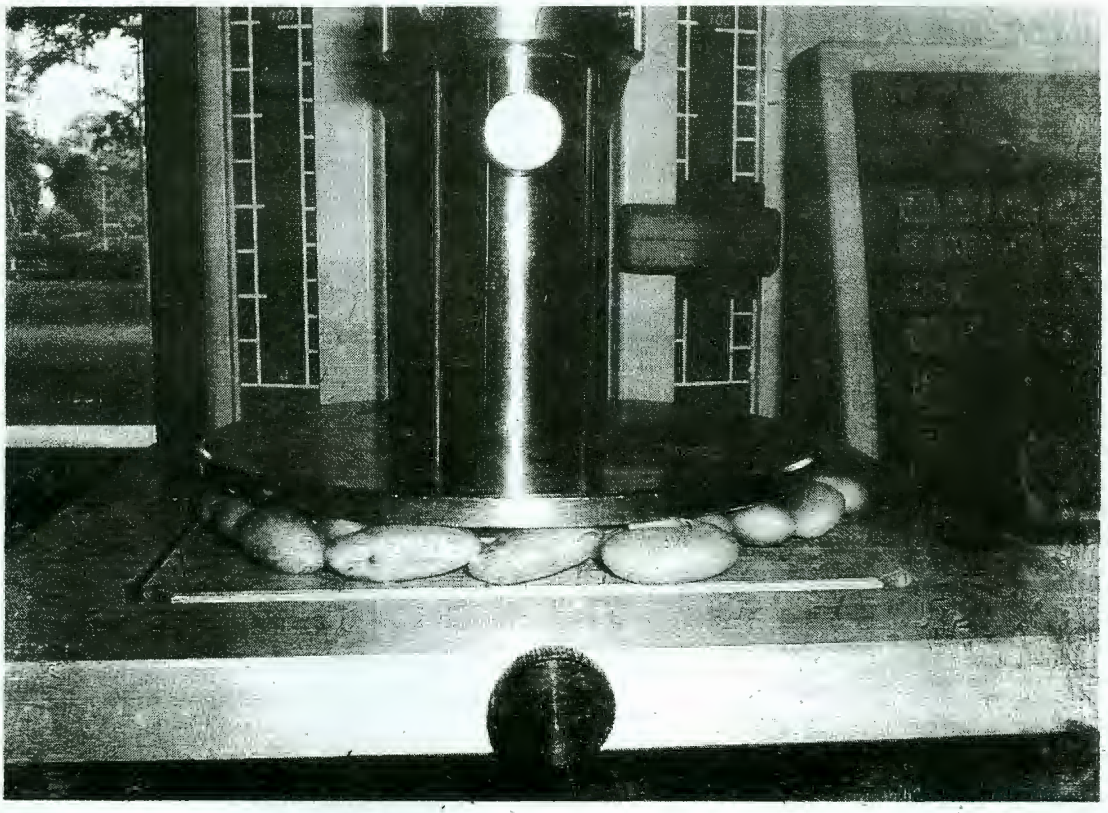

Figure 1: **Texture analyzer (Model LRX 5K, TA 500, LLOYD Instruments, England, 1998).**

Statistical analyses

Data were analyzed by analysis of variance (ANOVA). The Duncan multiple range tests were used to separate means and significance was accepted at $P \leq 0.05$.

Results and Discussion

Physicochemical properties

General characteristics and physicochemical properties such as seed density, seed mass, hydration capacity, hydration index, swelling capacity, swelling index, hydration coefficient, swelling coefficient and cooking time of eight varieties of dry beans are presented in Table 1 and Table 2. Density of the eight varieties of dry bean varied from 1.18 to 1.34 g/ml, the highest being in Mexican and the lowest being in Gobirasha. Mexican had a significantly ($P < 0.05$) higher density followed by Awash, Tabor and Beshbesh. Roba and Tabor, Awash and Mexican had similar density values.

Hydration capacity (g/seed) ranged from 0.08 to 0.19 among the different dry bean varieties (Table 2). Gofta had the minimum, whereas Awash had the maximum hydration capacity. Awash variety also had the highest hydration index followed by Mexican and Tabor. Gofta, having the lowest hydration capacity also had the minimum hydration index. Swelling capacity did vary significantly among the varieties in a similar manner of hydration capacity. Swelling index and hydration index had a similar trend for a specified variety among all the samples. Awash had the highest hydration capacity, hydration index, swelling capacity, swelling index, hydration coefficient and swelling coefficient. Hence, it would require less cooking time, which is useful for saving fuel energy.

Unhydrated seeds (hard or non - soakers) percentage among the eight varieties of bean varied from 1.52 to 40.33 (Table 3), the highest being in Gofta and the lowest being in Awash. The number of unhydrated seeds after soaking is also an indication for their respective cooking time. The high difference in unhydrated seeds among varieties clearly indicates the variation in hydration capacity between varieties

Based on these results, differences in cooking quality between the bean varieties are non-marginal. Unhydrated seeds are undesirable, and would increase cooking time which in turn increases fuel and energy consumption. Non-soaked (unhydrated) seeds correlated negatively with water absorbed and positively correlated with cooking time.

Table 1. General characteristics of haricot bean varieties

Varieties	Type	Origin	Seed mass[a] (g/100 seeds)	Seed density (g/ml)	Seed size[b]	Aspect
Roba	Food	CIAT	18.98 ± 0.01	1.25 ± 0.01	Small	Elongated
Gobirasha	Food	CIAT	43.94 ± 0.00	1.18 ± 0.01	Large	Elongated
Beshbesh	Food	CIAT	19.35 ± 0.01	1.25 ± 0.00	Small	Round
Gofta	Food	CIAT	31.21 ± 0.00	1.18 ± 0.00	Medium	Round
Awash	Export	CIAT	16.91 ± 0.01	1.33 ± 0.00	Small	Round
Mexican	Export	Kenya	17.85 ± 0.00	1.34 ± 0.00	Small	Round
Red wolaita	Food	Ethiopia	21.92 ± 0.01	1.22 ± 0.00	Small	Elongated
Tabor	Food	CIAT	18.29 ± 0.00	1.27 ± 0.00	Small	Elongated

[a] Mass of 100 dry bean seeds. [b] Small size, less than 25 g/100 seed or 3-4 mm; medium size, 25-40 g/100 seed or 4-6 mm; large size, greater than 40 g/100 seed or 6-8mm.

Table 2: Physicochemical properties of haricot beans

Varieties	Hydration capacity[a] (g/seed)	Swelling capacity[b] (ml/seed)	Hydration index	Swelling index	Hydration coefficient	Swelling coefficient
Roba	0.13 ± 0.00	0.14 ± 0.00	0.68 ± 0.00	0.93 ± 0.00	1.68 ± 0.01	1.58 ± 0.00
Gobirasha	0.12 ± 0.01	0.12 ± 0.00	0.26 ± 0.02	0.31 ± 0.00	1.26 ± 0.00	1.16 ± 0.00
Beshbesh	0.13 ± 0.00	0.14 ± 0.00	0.66 ± 0.01	0.90 ± 0.01	1.66 ± 0.00	1.55 ± 0.01
Gofta	0.08 ± 0.02	0.09 ± 0.01	0.26 ± 0.00	0.33 ± 0.00	1.26 ± 0.00	1.19 ± 0.00
Awash	0.19 ± 0.00	0.20 ± 0.01	1.28 ± 0.00	1.74 ± 0.00	2.28 ± 0.02	2.39 ± 0.01
Mexican	0.18 ± 0.01	0.18 ± 0.00	1.25 ± 0.01	1.74 ± 0.00	2.25 ± 0.00	2.56 ± 0.02
Redwolaita	0.12 ± 0.00	0.13 ± 0.00	0.56 ± 0.00	0.70 ± 0.01	1.56 ± 0.00	1.40 ± 0.00
Tabor	0.16 ± 0.01	0.17 ± 0.02	0.68 ± 0.00	0.93 ± 0.00	1.69 ± 0.01	1.54 ± 0.00

All values are the mean ± SD of three independent determinations.
[a] Mean increases in mass of seeds due to water uptake over 12 h divided by the number of seeds.

[b] Mean increases in volume of seeds due to water uptake over 12 h divided by the number of seeds.

Physicochemical characteristics, as mentioned above, are important parameters, which ultimately play an important role in cooking dry beans. The results of the present study are consistent with those mentioned by previous workers (Sharma, 1989; Latunda, 1991; Bishnoi and Khetarpaul, 1993; Wang *et. al.*, 2003) for other legumes. They reported that the legumes having higher hydration and swelling coefficients require less cooking time.

Hardness after cooking increases with a decrease of hydration capacity (g/seed) in different varieties, but decreases with cooking time. Hence, the consumers and processors alike prefer varieties with low cooking time and low hardness value.

A large hydration capacity leads to better cooking quality (less cooking time and texture) and quicker sprouting, so is ultimately desirable to the end-user. As cooking of some of the varieties would require less fuel and energy, they should be preferred.

Cooking time and texture measurements

Cooking time is one of the main considerations used for evaluating pulse cooking quality. Longer cooking times result in a loss of nutrients and could limit end-uses. Hence, consideration of cooking time is of paramount importance. The results obtained for cooking properties of haricot bean are given in Table 3. Awash and Gofta required the minimum and maximum cooking time of 19.50 and 41.70 min, respectively. As Mexican and Awash had higher hydration and swelling capacities, they required less cooking time.

The hardness of the cooked bean is defined as the maximum force required for 75% deformation of seeds after cooking. The force required for seed deformation was less for Awash and Mexican and these varieties also had the smallest cooking time. Hardness of dry beans ranged from 118.09 to 178.72 N g^{-1}, the highest being in Gofta and the lowest being in Awash (Table 3). Hardness values have similar correlation trends in cooking time reported by Wang *et. al.,* (2003). Most of the varieties studied had good cooking ability as easured hardness by LLOYDЖ texture analyzer.

Table 3. Cooking properties of haricot beans

Varieties	Hardness[a] (N g^{-1})	Water absorbed (%)	Unhydrated seeds[b] (%)	Cooking time in min. ± st.dev.
Roba	129.64 ± 1.22	167.36 ± 0.01	18.14 ± 0.02	24.03 ± 0.01
Gobirasha	152.57 ± 1.51	125.06 ± 0.18	37.18 ± 0.05	34.00 ± 0.00
Beshbesh	136.96 ± 0.96	165.41 ± 0.57	21.76 ± 0.01	26.61 ± 0.01
Gofta	178.72 ± 1.40	124.94 ± 0.13	40.33 ± 0.01	41.70 ± 0.05
Awash	118.09 ± 1.42	227.29 ± 0.11	1.52 ± 0.01	19.50 ± 0.05
Mexican	126.69 ± 1.15	224.38 ± 0.01	4.74 ± 0.01	22.50 ± 0.05
Redwolaita	140.98 ± 0.95	154.82 ± 0.06	31.59 ± 0.02	28.55 ± 0.10
Tabor	127.55 ± 0.97	167.50 ± 0.03	5.24 ± 0.01	23.60 ± 0.06

[a] Samples were cooked for their corresponding cooking times determined using the Mattson cooker and the force required for 75% deformation of seeds after cooking expressed in Newton per gram.

[b] Calculated as a percentage of number of unhydrated seeds after soaking overnight to the total number of seeds which initially has a mass of 100 g.

The force required to compress the cooked beans increased with increasing cooking time. Hence, hardness correlated negatively with hydration capacity and positively correlated with unhydrated seeds (%), and calcium content reported in later section. A few varieties were consistently found to be difficult to hydrate and cook to an acceptable texture. Gofta and Gobirasha were conspicuous in this Hard To Cook (HTC) phenomenon due to their high number of unhydrated seeds. Texture of cooked beans and color value are critical to consumer acceptability among a number of physical and chemical properties of dry and cooked bean seeds which are capable of differentiating culinary quality. The culinary quality of beans is the aggregate property that consumers and processors look for as a criterion towards acceptability. Hard to cook (HTC) defect is one of the most significant acceptability characteristic for haricot bean household consumption and industrial processing. Cookability of beans has been reported (Salunkhe, 1982) to depend upon such factors as growing conditions, handling and storage, chemical composition, beans microstructure (seed coat and cotyledon cell walls), and thickness of the palisade layer. Much research has been and is being conducted on these aspects and their interrelationships but no satisfactory solution to the hard bean problem has yet been found. In general, consumers prefer red/yellow colored seeds and quicker cooking times. The cooking time required for beans to reach an acceptable texture and texture characteristics of cooked beans are important factors influencing consumer's perception of bean quality (Chan and Watts, 1988).

Mineral composition

The cation concentration within bean seeds is presented in Table 4. Calcium, magnesium and potassium concentrations varied conspicuously according to bean types. Much greater amounts were found in beans with higher values of cooking time. Calcium, magnesium and potassium concentrations in beans might have a great influence on cooking time. Similarly, Patané *et. al.*, (2004) indicated that lower calcium content leads to a better seed cookability (cooking quality). The results indicated that cookability of haricot bean seed is influenced by its Ca and Mg concentrations (Jones and Boulter, 1983). Thus, Gofta with calcium, magnesium and potassium content of 1929.77 mg/kg, 1827.00 mg/kg and 16900.34 mg/kg had higher cooking time while Awash with 731.93 mg/kg calcium, 728.24 mg/kg magnesium and 14206.32 mg/kg potassium content respectively had lower cooking time. These mineral composition values are slightly lower than concentrations reported by Augustin *et. al.*, (1981). But they were greater than those reported by Barampama and Simard (1993).

Calcium, Mg and K are the principal cations present in dry bean seed (Human Nutrition Information Service, 1986). There is evidence that, proportionately, Ca concentration is more variable than that of Mg or K in bean commodity (Walker and Hymowitz, 1972). Both environmental and genetic factors influence Ca accumulation in bean seeds (Quenzer *et. al.*, 1978). However, little is known about factors influencing the distribution of Ca and associated cations within bean plants.

Accompanying phytochemicals in bean seeds reduce the bioavailability of bivalent and trivalent minerals.

Deposition of Iron varied from 61.81 (Tabor) to 84.00 mg/kg (Redwolaita). Iron values obtained are similar to or greater than concentrations given by many workers (Fordham *et. al.,* 1975; Barampama and Simard, 1993). Iron present in beans is nonheme form, and is only 0.8-5.2 mg/kg available (Lynch *et. al.,* 1984). Zinc concentrations in the eight varieties varied from a low of 15.39 mg/kg (in Tabor) to 28.22 mg/kg (in Redwolaita).

The zinc concentrations (60.35-80.79 mg/kg) in the dry beans reported by Barampama and Simard (1993) were greater than in the results of this work (15.39-28.22 mg/kg). Zinc is an essential trace element (micronutrient) for normal healthy growth and reproduction. Although zinc is less available for absorption from vegetable proteins than from meats, beans are significant source of dietary zinc (Murphy *et. al.*. 1975). Zinc deficiency is common in Africa and Asia, where people consume large quantities of milk, which is high in calcium and low in zinc. Starches and fibers present in their food also interfere with zinc absorption (Umeta *et. al.,* 2000). Zinco-protein supplementation of bean-based foods can reduce protein energy malnutrition (PEM) disease in general.

The Phosphorus concentrations in the eight varieties were found in the range of (147.99 mg/kg in Tabor to 173.99 mg/kg in Gobirasha) and were smaller than the concentrations reported by other researchers. Dry beans are good sources of dietary phosphorous in general.

Table 4. Mineral composition (mg/kg) of haricot bean varieties (mean ± SD, n=3)

Varieties	Minerals					
	Mg	K	Ca	Fe	Zn	P
Roba	898.14 ± 0.18	15498.19 ± 0.06	905.71 ± 0.10	63.14 ± 0.23	16.00 ± 0.02	158.97 ± 0.06
Gobirasha	1725.24 ± 0.06	16340.00 ± 0.18	1629.77 ± 0.16	79.31 ± 0.28	23.91 ± 0.16	173.99 ± 0.20
Beshbesh	1068.07 ± 0.16	15520.12 ± 0.12	1167.76 ± 0.17	62.71 ± 0.08	28.03 ± 0.22	161.44 ± 0.46
Gofta	1827.00 ± 0.12	16900.34 ± 0.15	1929.77 ± 0.16	62.26 ± 0.08	27.60 ± 0.13	167.96 ± 0.08
Awash	728.24 ± 0.05	14206.32 ± 0.17	731.93 ± 0.12	69.61 ± 0.03	17.21 ± 0.23	168.80 ± 0.06
Mexican	793.27 ± 0.19	14508.88 ± 0.16	854.34 ± 0.10	64.30 ± 0.01	17.91 ± 0.16	164.42 ± 0.08
Redwolaita	1452.04 ± 0.23	15789.57 ± 0.14	1346.91 ± 0.04	84.00 ± 0.08	28.22 ± 0.02	164.98 ± 0.10
Tabor	846.17 ± 0.11	15009.69 ± 0.10	895.74 ± 0.23	61.81 ± 0.00	15.39 ± 0.04	147.99 ± 0.02

Correlations between cooking quality and physicochemical properties

Many relationships between physicochemical properties like cooking time, swelling capacity, hydration index, hardness etc also are obtained. Cooking time is of importance as it is directly related to the energy expenses. Similarly, swelling capacity and hydration index (soaking characteristics) and texture of cooked bean etc also are related to cooking time. Beans that have low hydration capacity are, for example, not preferred by the processor as they require higher energy and time before they can be utilized.

Figures 2 to 5 indicate the correlations between some important parameters. Figure 2 showed that as swelling capacity increases the cooking time decreases for all the varieties studied. Figure 3 shows a relationship between the calcium content and cooking time. The maximum force required for deformation of seeds was correlated negatively with swelling capacity and furthermore positively correlated with cooking time (Figure 4). Expectedly there is also a positive relationship between swelling index and hydration index (Figure 5). The good correlations can be utilized in determining cooking time of such beans.

Seed - coat and cotyledon cell walls are of great interest from the standpoint of cookability and texture in dry beans (Bhatty, 1990; Shomer *et. al.*, 1990). The relationship between calcium content and cooking time is due to accumulation of most of the calcium taken up by the bean in the seed - coat and outer layers of the bean microstructure (John and Kenneth, 1999, Zhang *et. al.*, 2004,). Calcium cations which are accumulated in the bean seed - coat (palisade cells) reduce the permeability of seeds. Upsurge of calcium can result in augmenting the thickness of the palisade (the outermost cell layer of the seed coat) layer which is an important parameter in cooking quality (Reyes-Moreno and Paredes-López, 1993; Muller, 1967). This accumulation affects a decrease in water absorption capacity and loss of cooking ability of cotyledon and seed coat (De León *et. al.*, 1989) and alterations in texture, color and flavor (Varriano-Marston and Jackson, 1981). In brief, Ca, Mg and K concentrations in seed texture were negatively correlated with cooking time.

Additionally, accumulation of minerals on the seed - coat explain their nutrient retention values during cooking which was varied from 78.9 to 100% for Cu and Ca respectively (Augustin *et. al.*, 1981). Overall soil characteristics determine the proximate analysis, in particular the mineral composition of the beans, which in turn can determine the physicochemical characteristics like cooking time and cooked texture which are essential data for processing applications (John and John, 1996). Hence, the mineral composition of beans studied can be dependent on the soil characteristic where the beans are grown.

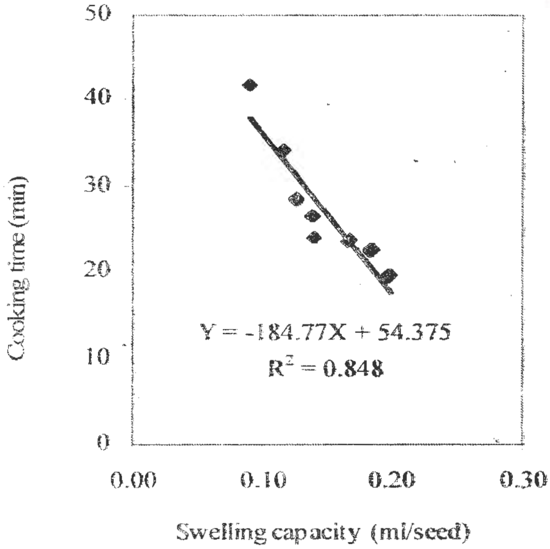

Figure 2: Cooking time and swelling capacity of haricot beans

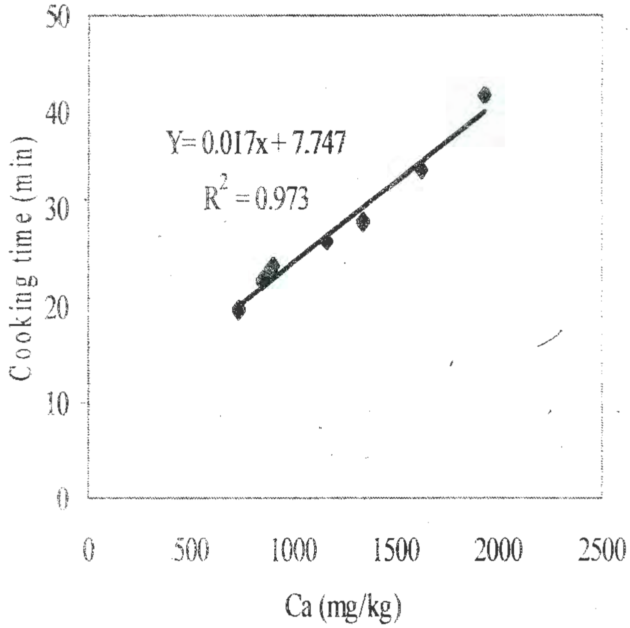

Figure 3: Cooking time and calcium content of haricot beans

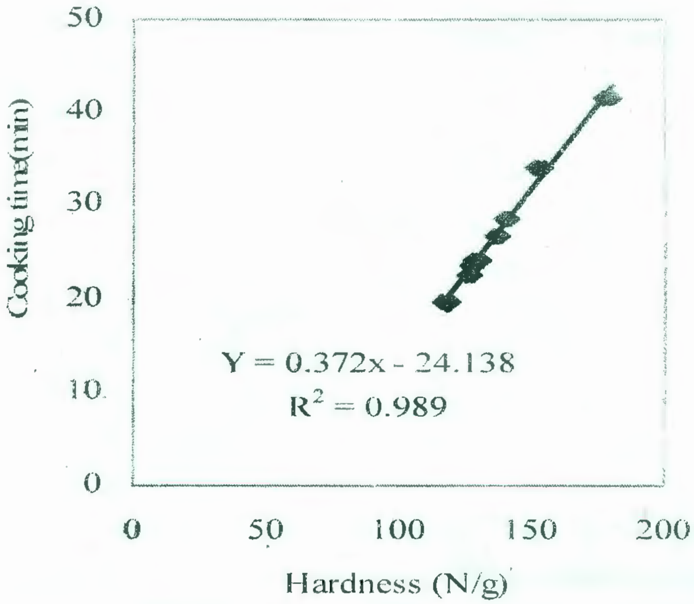

Figure 4: Hardness and cooking time relationship

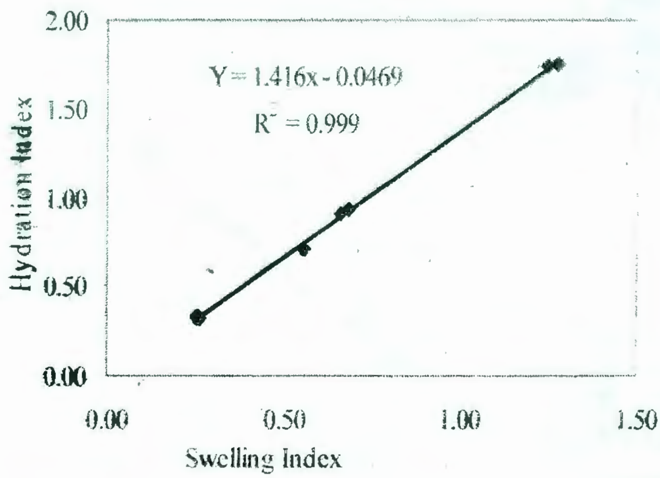

Figure 5: Relations on hydration and swelling indices of haricot beans

Conclusions

The results obtained indicated that cooking time is positively correlated to hardness. Haricot bean variety which have higher concentrations of Ca, Mg and K (Gofta variety) had higher cooking time, while bean varities which had lower Ca, Mg and K concentration (Awash variety) showed lower cooking time. Thus, concentrations of calcium, magnesium and potassium cations in bean samples have been positively correlated to cooking quality. Furthermore, it was also indicated that, haricot bean seed mass had a significant ($P< 0.05$) effect on swelling capacity and cooking quality of beans. Beans with lower values in seed mass exhibited higher swelling and water hydration capacity, shorter cooking time and softer texture after cooking. The force required to compress the cooked beans increased with increasing cooking time. Therefore, hardness correlated negatively with hydration and swelling capacity; and positively correlated with unhydrated seeds (%) and calcium content of the bean samples. Hardness is dependent on the mineral content of the haricot bean samples. It can be extrapolated that mineral content of beans which has great influence on cooking time and hardness depends on the soil nutrient composition. Hence, knowledge of the soil composition can be used to predict hardness and cooking time of the beans.

Among all the varieties studied, Awash, Mexican, Roba and Tabor exhibit good grain quality due to their cooking characteristic, physicochemical properties and cooked bean texture. Furthermore, Redwolaita has reasonable physicochemical properties and cooking quality. There are significant differences in the hardness, mineral and physicochemical composition between the studied bean varieties. It is of paramount importance that, before popularizing new varieties, they should be thoroughly analyzed for their acceptability characteristics. These traits include a wide variety of attributes, such as grain size, shape, color and appearance, stability under storage conditions, cooking properties, cooked texture (hardness), product obtained and nutritional quality.

Releasing new potential cultivars from agricultural research centres is an inevitable process. Hence, the improvement of the bean-grain quality will be achieved through the interaction established among the different disciplines, such as genetics, agronomy, crop protection, food process engineering, nutrition, research extension and socio-economics. In order to carry out further research study on product design and development of these bean varieties, supplementary data need to be succeeded on the phytochemical composition, amino acid profile, protein and starch *in vitro* or *in vivo* digestibility as affected by various processing methods.

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