Canning Quality Evaluation of Common Bean (*Phaseolus vulgaris* L.) Varieties Grown in the Central Rift Valley of Ethiopia

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Abstract: Selection of high canning quality common bean has a paramount importance in canning industryand canning quality is mostly evaluated by using combination of different parameters. The aim of this study was to evaluate the canning quality of common bean varieties together with physico-chemical properties, proximate composition, minerals, phytochemicals and bioavailability of micronutrients. Canning quality was evaluated by using three different canning mediums such as brine, brine with 10 mg $kg^{-1}CaCl_2$ and tomato sauce. In all three canning mediums, the common bean varieties showed significant differences in their canning quality traits. Percentage washed drained weight ranged between 55.05-62.66, 53.44-60.78, 51.34-56.77 for beans canned in brine, brine with 10 mg kg^{-1} $CaCl_2$ and tomato sauce, respectively. The results revealed the optimum hydration coefficient value of 1.8 for all common bean varieties. Visual appearances, splits, degree of clumping, starchiness, flavor and taste and seed size were also determined through a visual rating procedure as canning quality traits. Awash Melka and Awash-1 bean varieties revealed a good canning quality and Argene bean variety also showed a promising canning quality. However, Chercher and Omer bean varieties were not good enough for canning purpose. Therefore, the information generated in this study could be used by government, agricultural research centers, bean exporters or other stakeholders to enhance production and export of high canning quality common bean varieties.

Keywords: Bean Canning Process; Bioavailability of Micronutrients; Common Beans; Canning Mediums; Canning Quality

1. Introduction

Grain legumes play an important role in the world's food and nutrition requirements, especially in the dietary pattern of low-income group of people in developing countries. They are considered as "resource poor meat" and are important inexpensive sources of protein, dietary fiber, and starch. They contain almost two to three times more protein than cereals. Because of their high protein and lysine content, they also represent good sources of supplementary protein when added to cereal grains and root crops, which are low in essential amino acids (Perla *et al*., 2003).

Common bean (*Phaseolus vulgaris L.*) is the most important food legume either as a source of protein for local consumption or as an export crop for generating foreign currency in Ethiopia (Tadele, 2006). This crop was introduced to the northern parts of the country around the 16th century (Shimelis and Rakshit, 2005a). Common bean has a wide range of adaptation and its production is very heterogeneous in terms of ecology, cropping system and agronomic performance. It is one of the most important grain legumes grown in the low lands of Ethiopia particularly in the Central Rift Valley of Ethiopia. In these areas, smallholder farmers grow white pea beans for export and food type colored beans for house hold consumption.

Ethiopia, endowed with varied agro-ecological zones and diversified natural resources, has been known as the homeland and domestication of several crop plants. Common beans are important components of crop production in Ethiopia's smallholders' agriculture, providing an economic advantage to smallholder farmers as an alternative source of protein, cash income, and food security. Previously, the aim and goal of Ethiopian agricultural research centers were only to release improved bean varieties in terms of high yield or productivity per hectare, and drought and disease resistance from their plant breeding and crop protection perspectives. Very little was known about the canning quality of common bean varieties. Due to unavailability of canning quality laboratory in Ethiopia, up to now canning analysis is done in South Africa and some genetically potential bean varieties for canning may be copied. This gap did not allow intensive utilization of different common bean varieties as a value added product efficiently.

Common beans are generally subjected to various treatments, such as storage under different environmental conditions, soaking in water or salt solutions, cooking at normal or elevated pressure, frying after cooking prior to consumption or they are used as germinated and cooked beans (Reddy *et al*., 1984). Among different physical treatments used to process common beans canning is one method which increase the shelf stability of the bean products. Canning of beans is mainly composed of two processes, namely the soaking/blanching process and thermal processing/heat sterilization. The purpose of soaking before canning is

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to remove foreign material, facilitate cleaning, aid in can filling through uniform expansion, and ensure product tenderness and to improve color (Uebersax *et al*., 1987). The main purpose of blanching is the inactivation of enzymes, which might produce off flavors, but also to soften the product and remove gasses to reduce strain on can seams during retorting (Jones & Beckett, 1995). The purpose of this study is to evaluate canning qualities of five different common bean varieties grown in the Central Rift Valley of Ethiopia.

2. Materials and Methods

Common bean varieties, namely Awash-1, Awash Melka, Argene, Chercher and Omer were collected from Melkasa agricultural research center. The common bean seeds were hand cleaned to remove any foreign matters that come along with the beans and visually inspected in order to remove any physically damaged bean, bean with damaged seed coat, bean with fade color and undesirable type of shapes. For each variety about 1.5 kg sample was taken for the study and packed in plastic bags.

2.1. Process Technology of Bean Canning

The canning procedure was performed according to a method described by Hosfield and Uebersax (1984). Common bean samples were taken and soaked for 30 minutes at room temperature, blanched for 30 minutes at 88°C and filled into cans (equivalent of 96 g soaked, blanched beans). Three different canning mediums; brine solution, brine solution together with about 10 mg kg^{-1} of calcium chloride and tomato sauce were used in this study. Cans were filled with brine, about 10 mg kg^{-1}calcium chloride with brine and tomato sauce independently up to a final weight of about 410g. At last the cans were retorted by Dixons instruments autoclave (model ST18, 2005, England) at 121.1°C for 30 minutes at pressure of 15 psi(Pascal second inch) followed by instant cooling in running tap water for 20 minutes. A storage period of two weeks was allowed after canning before reopening the cans for testing. Thereafter, beans were drained and washed in tap water to remove the tomato sauce.

One-piece can with dimension of 73 × 110mm (D×H) and 73mm ends were used for this study. Distilled water was used for soaking, blanching and brine preparation otherwise about 10 mg $kg^{-1}$of calcium chloride was used in soak water and blanch water when beans were canned in brine solution together with about 10 mg kg^{-1} calcium chloride. Sealing was done with Dixie automatic can double seamer (Model 25D-600, Dixie Canner Co., Athens, Georgia, USA, Year of manufacture, 2004).

2.2. Proximate, Minerals and Phytochemicals Composition Analyses

Moisture content, total ash, crude fat, crude protein and crude fiber were determined by AOAC (2000) official methods of 925.10, 923.03, 920.39, 920.87 and 945.38; respectively. The difference was taken as total carbohydrates content. The minerals composition was determined by flame atomic absorption spectrometry and flame photometry according to the methods 923.03 of the AOAC (2000). Energy value was quantified according to Gaman and Sherrington (1986) based on the three groups of nutrients (carbohydrates, fats and proteins). Phytic acid composition was evaluated using the method of Haug and Lantzsch (1983) and Tannin was determined by the modified Vanillin assay method described by Butter *et al.* (2000).

2.3. Physico-chemical Properties

Hundred seed weight, density, hydration coefficient, swelling coefficient, hydration capacity, swelling capacity, hydration and swelling index and seed coat to whole seed weight ratio were determined according to the methods described by Hosfield and Uebersax (1980), Bishnoi and Khetarpaul (1993), and Shimelis and Rakshit (2005a). Cooking time was estimated according to the method of Morris (1963) using the Mattson cooking device.

2.4. Canning quality Evaluation of Beans

Hydration coefficient of the canned bean was determined by the procedure of Hosfield and Uebersax (1980). The drained weight of the processed beans was determined by the procedure of Balasubramanian *et al.* (1999). Other canning parameters were measured by a visual rating procedure (visual estimation). A 5point scale was used for visual appearance (1 = poor to 5 = excellent); 10 point scale was used for splitting (1 = completely broken or mushy bean to 10 = beans without cracks, splits and loose skins); 3 point scale was used for expressing degree of clumping (1 = beans solidly clumped to the bottom of the can to 3 = no clumping); starchiness (1 = very clear to 5 = extremely cloudy); 5 point scale was used for flavor and taste (1 = unpleasant flavor to 5 = good flavor) and a 7 point scale was used for seed size (1 = unevenly sized to 7 = uniform seed size).

2.5. Statistical Analysis

All data were analyzed by JMP 5.0 software using one way analysis of variance (ANOVA). Significance was accepted at 0.05 level of probability ($P < 0.05$) and finally canning quality of bean varieties was estimated. Pearson's correlation between physico-chemical properties and chemical composition with canning qualities were analyzed using SPSS 20.

3. Results and Discussion

3.1. General Characteristics of Common Bean Seeds

The seed density (1.21 g ml^{-1}) of Awash-1 was the largest and the lowest seed weight was obtained for Omer (1.12 g ml^{-1}). But among the seed densities, only the seed density of Omer was significantly different ($P < 0.05$) from the seed densities of the other four varieties of common bean (Table 1). The hundred seed weight (46.10 g per 100 seeds) of Omer was the largest compared to the rest common bean varieties and Argene had the lowest hundred seed weight (15.56 g per 100 seeds). All five varieties of common bean showed significant differences ($P < 0.05$) in their hundred seed weight.

The common bean seed densities reported by Shimelis and Rakshit (2005a) were between 1.18 g ml^{-1} and 1.34 g ml^{-1}. The results obtained in this study are almost similar with seed densities obtained by Shimelis and Rakshit (2005a). The general seed characteristics of the varieties obtained in this study have similar value when compared with findings reported by Olang'o *et al.* (2000) for five Kenyan dry bean varieties and that of Mario *et al.* (2009) reported for fifty dry beans in Chile.

Table 1. General characteristics of common bean varieties.

Varieties	Type	Seed weight^y (g per 100 seed)	Seed density (g ml^{-1})	Seed size^z	Aspect
Awash-1	Export	16.89±0.41^d	1.21±0.02^a	Small	Round
Awash Melka	Export	18.24±0.46^c	1.17±0.00^a	Small	Round
Omer	Export	46.10±0.72^a	1.12±0.00^b	Large	Elongated
Chercher	Export	19.31±0.49^b	1.17±0.02^a	Small	Round
Argene	Export	15.56±0.21^e	1.19±0.01^a	Small	Round

^{y} Weight of 100 common bean seeds ;^{z} Small size, less than 25 g per 100 seed or 3-4 mm; medium size, 25-40 g per 100 seed or 4-6 mm; large size, greater than 40 g per 100 seed or 6-8mm (Shimelis and Rakshit, 2005); Means within same column followed by the same letters are not significantly different; (P > 0.05); All values are mean ± SD of three independent determinations.

3.2 Physico-chemical Properties

Hydration capacity (g seed-1) ranged from 0.133 to 0.337 among the different common bean varieties (Table 2). Argene had the minimum hydration capacity whereas Omer had the maximum hydration capacity. Argene revealed minimum hydration coefficient followed by Awash-1, Chercher, Awash Melka and Omer. The maximum swelling capacity was found in Omer and the minimum swelling capacity was observed in Argene. Omer, Awash Melka, Chercher, Awash-1 and Argene showed decreasing order of hydration and swelling index. Argene had the minimum swelling index whereas Omer had the maximum swelling index. Omer had the maximum hydration coefficient, swelling coefficient, hydration index and swelling index. Hence, it requires less cooking time compared to the other varieties. The results of the present study are consistent with the research finding presented by Shimelis and Rakshit (2005a).

Furthermore, this result is consistent with the work of Magdalena (2004). Daleen *et al.* (2006) reported that hydration coefficient was between 1.73 and 1.81, which is similar with the finding of this specific study. The work done by Balasubramanian *et al.* (1999) also shows linearity in the physico-chemical properties when compared to the resultsobtained in this study.

Table 2. Physico-chemical properties of common bean varieties.

Varieties	Hydration capacity^y (g/seed)	Swelling capacity^z (mL/seed)	Hydration index	Swelling index	Hydration coefficient	Swelling coefficient
Awash-1	0.139±0.01^{bc}	0.141±0.00^c	0.806±0.03^{bc}	1.022±0.01^b	1.819±0.03^c	2.032±0.01^{cd}
Awash Melka	0.156±0.01^b	0.161±0.00^b	0.848±0.04^{ab}	1.073±0.01^a	1.871±0.01^b	2.074±0.01^{ab}
Omer	0.377±0.02^a	0.399±0.01^a	0.877±0.01^a	1.083±0.02^a	1.884±0.02^a	2.089±0.02^a
Chercher	0.156±0.00^b	0.161±0.00^b	0.837±0.02^{abc}	1.025±0.03^b	1.836±0.03^{bc}	2.058±0.03^{bc}
Argene	0.133±0.01^c	0.127±0.00^d	0.798±0.01^c	0.987±0.02^c	1.813±0.04^c	2.012±0.01^d

All values are mean ± SD of three independent determinations; ^{y} Mean increases in weight of seeds due to water uptake over 24 h divided by the number of seeds; ^{z} Mean increases in volume of seeds due to water uptake over 24 h divided by the number of seeds; Means within same column followed by the same letters are not significantly different (P> 0.05).

The cooking time of common varieties together with seed coat to whole ratio were presented in Table 3. Omer variety require less cooking time of 25 minutes and Argene variety require maximum cooking time of 34.33 minutes when compared to the other bean varieties. Common bean with high hydration and swelling capacity revealed lower cooking time. Cooking time is one of the main considerations used for evaluating beans cooking quality. Longer cooking time result in a loss of nutrients and could limit end-uses.

Generally cooking quality is the aggregate of properties perceived as influencing consumer preferences and overall acceptability. Seed coat to the whole seed ratio of common bean varieties ranged from 8.42 to 9.66% in which Awash Melka has the highest ratio (9.66%) and the lowest ratio (8.42%) was observed for Argene bean variety. Consistent with the results of this study, Beninger and Hosfield (1997) reported that seed coat to whole seed ratio range from 6.5% to 9.8% for eight common bean varieties. Bassinello *et al.* (2005) on their research work entitled canning quality and common bean preference in Brazil showed that the seed coat to the whole seed ratio for eleven common bean varieties were between 7.87 and 11.29%. Both research findings have resemblance with this specific study.

Table 3. Cooking time and ratio of seed coat to the whole seed of common bean varieties.

Varieties	Seed coat to whole seed ratio ^{y} (%)	Cooking time(minutes)
Awash-1	9.07±0.16^{b}	30.33±1.52^{b}
Awash Melka	9.66±0.07^{a}	27.00±1.00^{c}
Omer	8.87±0.01^{bc}	25.00±1.00^{d}
Chercher	8.58±0.18^{c}	28.66±0.57^{bc}
Argene	8.42±0.03^{c}	34.33±1.15^{a}

Means within same column followed by the same letters are not significantly different (P> 0.05); All values are mean ± SD of three independent determinations; ^{y} *ratio of seed coat weight to the whole seed weight*

3.3 Proximate Composition of Common Bean Seeds

There were significant differences ($P < 0.05$) among the common bean varieties in their nutritional composition as indicated in Table 4. Moisture content concentrations varied from 10.13 (Awash Melka and Omer) to 10.27 (Chercher). The crude protein varied from 22.15 (Chercher) to 26.97 (Awash Melka) whereas crude fat varied from 0.56 (Omer) to 1.65 (Awash Melka). Then the minimum total ash was obtained for Awash-1 and the maximum total ash was obtained for Cherchervariety. Crude fiber varied from 4.86 to 7.01 and the minimum and maximum total carbohydrates was observed for Awash Melka and Chercher varieties; respectively.

Proximate composition varied from variety to variety but the results show similarity with the previous work done by Magdalena (2004), Shimelis and Rakshit (2005a), Maurice and Elizabeth (2008), and Samman *et al.* (1999).

Table 4. Proximate composition of five common bean varieties of whole seed sample (g per 100 g DM^{y}).

Varieties	Moisture	Crude protein	Crude fat	Total ash	Crude fiber	Total carbohydrates
Awash-1	10.14±0.03^{a}	25.66±0.66^{ab}	0.99±0.14^{bc}	4.54±0.32^{a}	5.63±0.25^{ab}	58.66±0.87^{b}
Awash Melka	10.13±0.01^{a}	26.97±1.03^{a}	1.65±0.09^{a}	4.59±0.05^{a}	6.11±1.27^{ab}	56.66±0.98^{c}
Omer	10.13±0.01^{a}	23.83±0.70^{cd}	0.56±0.13^{c}	4.63±0.06^{a}	4.86±1.21^{b}	60.85±0.79^{a}
Chercher	10.27±0.12^{a}	22.15±0.36^{d}	1.25±0.23^{ab}	4.71±0.07^{a}	7.01±0.26^{a}	61.63±0.08^{a}
Argene	10.21±0.09^{a}	24.86±0.24^{bc}	1.51±0.35^{ab}	4.55±0.23^{a}	7.01±0.16^{a}	58.87±0.02^{b}

Means within same column followed by the same letters are not significantly different (P> 0.05); All values are means of duplicate ± standard deviation; ^{y}*DM, each values expressed on dry matter basis.*

Mineral Composition

The mineral compositions of the five common bean varieties were presented in Table 5. The bean varieties varied significantly in their mineral content (P < 0.05). The result revealed that all five varieties have a very high amount of potassium compared to other minerals. The results demonstrate similarity with previous work done by Barampama and Simard (1993), Shimelis and Rakshit (2005a) and Samman *et al.* (1999).

Table 5. Mineral composition (mg kg^{-1}) and energy contents (kJ per 100 g) of common bean varieties.

Varieties	Minerals						Energy value
	Na	K	Ca	Fe	Zn	P	(kJ per 100g)
Awash-1	38.9±1.62^{a}	19805.4±1.76^{a}	700.5±1.06^{b}	57.3±1.06^{d}	19.7±0.67^{b}	319.6±0.97^{d}	1388.94
Awash Melka	33.9±0.70^{b}	18245.7±1.20^{d}	656.5±0.35^{d}	65.1±0.63^{c}	17.3±0.99^{c}	273.8±0.74^{e}	1404.36
Omer	35.9±0.42^{b}	18467.4±2.33^{c}	633.0±0.98^{e}	72.4±0.70^{a}	14.3±0.61^{d}	686.5±1.27^{b}	1348.30
Chercher	39.5±0.98^{a}	19186.3±2.19^{b}	672.2±0.97^{c}	46.8±0.98^{e}	22.1±0.72^{a}	534.8±1.34^{c}	1386.58
Argene	33.8±0.56^{b}	17611.3±1.41^{e}	912.0±0.56^{a}	67.3±0.07^{b}	22.9±0.19^{a}	762.4±1.44^{a}	1398.44

Means within same column followed by the same letters are not significantly different (P> 0.05); All values are means ± SD.

The calcium concentrations varied conspicuously among the common bean varieties and ranged between 633.0 to 912.0 mg kg^{-1}. A similar range of Ca content (731-1929 mg kg^{-1}) was reported for common bean varieties grown in Ethiopia by Shimelis and Rakshit (2005a). Calcium concentrations in beans might have a great influence on cooking time. Accordingly, Argene, which had the highest Ca content compared to the other varieties, also, had the highest cooking time of 34.33 minutes. Similarly, Omer variety having lower calcium content revealed short cooking time of 25 minutes.

3.4. Bioavailability of Micronutrients

The mineral content of legumes is generally high, but the bioavailability is poor due to the presence of phytate, which is a main inhibitor of Fe and Zn absorption. The phytate/Fe molar ratio has been used as an indicator of iron bioavailability in beans (Ariza-Nieto *et al*., 2007). In this study, the highest phytateFe per molar ratio was observed for Awash-1 variety and the lowest was observed for Omer variety. The Argene, Chercher and Awash Melka contain phytate per Fe molar ratio next to Awash-1, respectively and the least ratio was obtained in Omer. The phytate per Zn molar ratio ranged from 66.58 to 118.73. The highest value being observed in Awash-1 variety followed by Awash Melka, Argene, Omer and Chercher; respectively. Similar values in phytate/Zn molar ratio have been reported previously for common beans by Maldonado *et al.* (2000).

The phytic acid × (calcium per zinc) [PA × (Ca per Zn)] molar ratio ranged from 1.12 (Chercher) to 2.15 (Argene). These values are generally lower than those reported by Maldonado *et al.* (2000). Growth depressing effects due to zinc bioavailability based on PA × (Ca per Zn) molar ratio are considered to be severe when the ratio exceeds 3.5 (Fordyce *et al*., 1987).

Table 6. Bioavailability of minerals in common bean varieties.

Varieties	Phytate/Fe [a] (molar ratio)	Phytate/Zn [b] (molar ratio)	Ca/phytate[c] (molar ratio)	[Phytate× (Ca/Zn)] [d] (mol kg^{-1})
Awash-1	35.15±0.65	118.73±2.08	0.48±0.00	2.07±0.07
Awash Melka	25.63±0.25	112.18±1.46	0.55±0.02	1.84±0.11
Omer	15.83±0.15	92.70±0.97	0.77±0.01	1.46±0.06
Chercher	27.09±0.57	66.58±2.17	0.74±0.01	1.12±0.03
Argene	27.66±0.02	94.28±0.81	0.68±0.02	2.15±0.02

Values within the same column with different superscript letters are significantly different from each other (P < 0.05); All values are mean ± SD; [a] = mg of Phytate/MW of Phytate: mg of iron/MW of iron; [b] = mg of Phytate/MW of Phytate: mg of Zinc/MW of Zinc; [c] = mg of Calcium/MW of Calcium: mg of phytate/MW of phytate[d] = (mol/kg Phytate) x (mol/kg Calcium)/(mol/kg Zinc)

Generally, similar trends of high phytate × (Ca per Zn) ratio, phytate per Fe, phytate per Zn and Ca per phytate ratio were observed for the five common bean varieties confirming their potential inhibitory effects on zinc, calcium and iron bioavailability. Chercher may be considered to be the best variety in termsof mineral bioavailability due to its low phytate per mineral ratio when compared to the other varieties. Therefore, this variety could be recommended for local bean based products development and consumption pattern due to its increased micronutrient bioavailability in order to fight micronutrient deficiencies among the critically vulnerable groups such as children, pregnant and lactating women.

3.5. Phytochemicals Composition

Phytochemicals are capable of reducing the nutritional values of beans by limiting the digestibility of proteins and carbohydrates (e.g., enzyme inhibitors, lectins and tannins) or by reducing the biological availability of minerals (Shimelis and Rakshit, 2005b). The phytate composition of the five common bean varieties ranged from 13.51 to 23.76 mg g^{-1}. The highest value of phytate was observed for Awash-1 followed by Argene, Awash Melka, Chercher and Omer, respectively.

Shimelis and Rakshit (2005b) have reported eight common bean varieties grown in Ethiopia with concentrations of phytic acid from 16.81 to 24.07 mg g^{-1} and Deshpande and Cheryan (1983) have reported dry bean varieties grown in the USA with concentration of phytic acid ranged from 18.1to 27.5 mg g^{-1}. Dave *et al.* (2008) also reported in their findings that phytic acid ranges between 16.7 to 25.1 mg g^{-1} for ten dry bean varieties grown in Canada. Their findings were almost similar to this study. Masum *et al.* (2011) also reported that phytic acid concentration between 12.52 to 316.42 mg kg^{-1} for 29 dry bean varieties grown in USA.

Table 7. Phytochemicals composition of common bean varieties.

Varieties	Phytochemicals composition (mg g^{-1})	
	Phytate	Tannins
Awash-1	23.76	9.32
Awash melka	19.68	13.17
Omer	13.51	21.10
Chercher	14.94	13.21
Argene	21.96	11.37

The amount of tannins found in common bean varieties which were used in this study ranged from 9.32-21.10 mg g^{-1}.

Consistent with the results of this study, Giami and Okwechime (1993) reported concentration of tannin for four dry bean varieties between 0.11 to 28.78 mg g^{-1}. Tannins concentration reported by Sathe *et al.* (1983) and Aw and Swanson (1985) showed consistency with the results obtained in this study.

3.6. Canning Quality Evaluation of Common Bean Varieties

All canning quality parameters had different values for various common bean varieties. This shows canning quality depends on the variety, environmental, and genetic diversity. The evaluation of canning quality was done by using three canning mediums: brine solution, brine solution together with 10 mg kg^{-1} of calcium chloride and tomato sauce.

Table 8. Canning quality of common beans canned in brine solution.

	Varieties				
Canning quality parameters	Awash-1	Awash Melka	Chercher	Argene	Omer
HC	1.77	1.79	1.84	1.81	1.67
PWDWT (%)	60.68	62.66	55.05	57.13	58.53
VA (1-5)	3.80	5.00	2.40	3.40	4.60
Splits (1-10)	6.60	9.20	4.20	6.40	8.60
Degree of clumping (1-3)	2.80	3.00	1.20	1.60	2.80
Starchiness (1-5)	2.40	1.60	4.00	2.80	1.80
Flavor and taste (1-5)	4.00	4.80	3.20	3.80	4.00
Seed size (1-7)	6.00	6.80	4.20	5.80	6.00

Where: HC- Hydration coefficient; PWDWT- Percentage washed drained weight; VA-Visual appearance

Table 8 provides canning quality of common bean varieties canned in brine solution. Significant differences were observed in all canning quality parameters for all varieties. Hydration coefficient ranged from 1.67 to 1.84 in which Chercher had the maximum hydration coefficient and Omer had the minimum value of hydration coefficient. A hydration coefficient of 1.8 is usually considered optimal for dry beans (Hosfieldand Uebersax, 1984; Hosfield and Uebersax, 1991). Hosfield and Uebersax (1980) found that the hydration coefficient of seven varieties of white dry beans ranged between 1.82 and 1.94 and revealed significant difference at $P < 0.01$ between bean types.

Awash Melka had the highest percentage washed drained weight which was 62.66% among the common bean varieties and the minimum was observed for Chercher which was 55.05%. Drained weight of common beans relates to "processors yield" (Varner and Uebersax, 1995), as it would require fewer beans with a high washed drained weight to fill a can compared to the case of beans with low washed drained weight. According to the Canadian government regulations for canned beans, the percentage washed drained weight of common beans should be at least 60% (Balasubramanian *et al.*, 1999). In the Ethiopian context, yet there are no approved quality standards/regulations for quality evaluation of canned common beans and bean based products. For that reason, the aforementioned Canadian quality assessment procedure/regulation was used as a benchmark in order to evaluate the Ethiopian bean based products. Results of percentage washed drained weight in this study is in agreement with those obtained by Balasubramanian *et al.* (2000) and Van der Merwe *et al.* (2006).

Table 9. Canning quality of common beans canned in brine solution together with 10 mg kg^{-1}calcium chloride.

	Varieties				
Canning quality parameters	Awash-1	Awash Melka	Chercher	Argene	Omer
HC	1.74	1.78	1.82	1.79	1.66
PWDWT	59.00	60.78	53.44	55.06	56.29
VA (1-5)	4.20	5.00	3.20	3.60	4.40
Splits (1-10)	8.20	9.60	6.80	7.00	8.80
Degree of clumping (1-3)	3.00	3.00	2.20	2.20	3.00
Starchiness (1-5)	1.80	1.00	2.80	2.60	1.40
Flavor and taste (1-5)	4.20	5.00	4.00	3.80	3.40
Seed size (1-7)	6.00	7.00	5.00	5.60	6.00

Where: PWDWT-Percentage washed drained weight; VA-Visual appearance; HC-Hydration coefficient

The visual appearance (1-5) ranged from 2.4 to 5, in which Awash Melka had the maximum followed by Omer, Awash-1, Argene and Chercher, respectively. Awash Melka had the maximum split value of 9.2 and the minimum split value was 4.2 (Chercher). Degrees of clumping (1-3), starchiness (1-5), flavor and taste (1-5) and seed size (1-7) were also conducted in all canning mediums. In all canning quality parameters performed, Awash Melka bean variety revealed superior canning quality results.

Calcium chloride is used in the canning industries to enhance the firmness of canned vegetables/pulses. In canned beans, the formation of metal-pectin complex may contribute to the toughening of seed coat and the turgidity of cell walls of the cotyledon tissue (Balasubramanian *et al.* 2000; Lange and Labuschagne, 2000). The canning quality of beans canned in brine solution treated with 10 mg kg^{-1} of calcium chloride is presented in Table 9. The hydration coefficient ranged from 1.66 to 1.82. However, Chercher had the highest value followed by Argene, Awash Melka, Awash-1 and Omer, respectively.

According to the research finding reported by Balasubramanian *et al.* (2000), addition of calcium reduces the hydration coefficient; percentage washed drained weight and splits during canning. The percentage washed drained weight had values ranging from 53.44 to 60.78%, in which Awash Melka variety had the highest value and Chercher had the lowest value among the five common bean varieties. The splits (1-10), visual appearance (1-5), degree of clumping (1-3) and starchiness (1-5) were improved when calcium was added in soaking, blanching and canning processes. Awash Melka had the highest value in visual appearance, splits, degree of clumping and starchiness with 5, 9.6, 3 and 1.0, respectively.

Percentage washed drained weight ranged from 51.34 to 56.77 for beans canned in tomato sauce (Table 10). The highest percentage washed drained weight was observed for Awash-1 common bean variety and the lowest was obtained for Omer variety.

When we compare the values of percentage washed drained weight of beans canned in brine solution with and without addition of calcium chloride with beans canned in tomato sauce, there was a noticeable reduction. Tomato sauce had lower pH values, which could have caused the inhibition of swelling, perhaps caused by insoluble complexes that were formed by organic acids and amylose in the beans which reduced the swelling of protein and starch.

Visual appearance (1-5) ranged from 3.0 to 5.0, splits (1-10) ranged from 8.2 to 9.4, degree of clumping (1-3) ranged from 1.2 to 2.8, and starchiness (1-5) ranged from 1.2 to 2.2. Splits were minimized during canning of beans in tomato sauce. The potential reason for this includes heat penetration and the level of calcium in tomato sauce. Heat penetration proceeds rapidly in the products with water, thin syrup or brine. The osmotic pressure of tomato sauce could also have been higher than that of brine, since increased levels of solids are present in the latter. Beans are evaluated for intactness, splits, free seed coats and brine consistency (Balasubramanian *et al.*, 1999). From the experiment it was observed that there was no starchiness in each bean varieties because starchiness depends on the tendency of beans to split.

Table 10. Canning quality of common bean varieties canned in tomato sauce.

	Bean variety				
Canning quality parameters	Awash-1	Awash Melka	Chercher	Argene	Omer
HC	1.77	1.79	1.84	1.81	1.67
PWDWT	56.77	55.40	53.85	53.03	51.34
VA (1-5)	4.60	5.00	3.00	3.80	4.20
Splits (1-10)	8.80	9.20	8.20	8.80	9.40
Degree of clumping (1-3)	2.80	3.00	1.20	2.00	2.40
Starchiness (1-5)	1.20	1.20	2.20	2.00	1.20
Flavor and taste (1-5)	4.40	3.40	3.40	3.80	4.40
Seed size (1-7)	6.20	6.00	5.00	5.80	6.00

Where: HC- Hydration coefficient; PWDWT- Percentage washed drained weight; VA-Visual appearance..

3.7. Effect of Canning Process on the Reduction of Phytochemicals

A number of treatments are convenient to remove or inactivate phytochemicals in legume seeds (Shimelis and Rakshit, 2007). These treatments can be classified mainly into chemical and physical ones. Table 11 shows the phytochemicals of the common bean varieties after heat treatment (autoclaving) process. From the figures obtained it was observed that phytate and tannins can be reduced in large amounts by high temperature processing. All varieties showed almost similar trend in the phytate reduction by percentage with Chercher (67.09%), Awash Melka (66.76%), Argene (66.03%), Omer (65.15%) and Awash-1 (62.03%). Maximum percentage reduction in tannin was obtained in Awash-1 and Argene varieties followed by Chercher, Awash Melka and Omer, respectively.

Beans are generally soaked and cooked to render the seeds palatable, inactivate heat labile phytochemicals, and permit the digestion and assimilation of protein and starch (Deshpande and Cheryan., 1983). The results obtained in this study were akin with the results obtained by Shimelis and Rakshit (2007). Muzquiz *et al.* (1999) in their research investigation of phytochemicals in common beans stated the level of reduction of phytate and tannins which is in agreement with the results obtained in this study.

Table 11. Effect of canning on the reduction of phytochemicals composition.

Varieties	Phytate ($mg\ g^{-1}$)	Percentage of Reduction (%)	Tannins ($mg\ g^{-1}$)	Percentage of Reduction (%)
Awash-1	9.02	62.03	BDL	100
Awash melka	6.54	66.76	3.28	75.09
Omer	4.71	65.15	8.21	61.09
Chercher	4.92	67.09	2.55	80.69
Argene	7.46	66.03	BDL	100

Where: BDL-Below detection limit

3.8 Correlation Matrix between Chemical Composition and Canning Quality Attributes of Common Beans

The proximate analysis of the beans indicated a wide range of values for the varieties studied (Table 4). Correlations between chemical composition of raw common beans and canning quality may provide important information for breeders to envisage early common bean generation lines for improved canning quality (Occeńa *et al*., 1992). Table 12 indicate the correlation between chemical composition and canning quality attributes when the beans are canned in brine solution, brine solution together with 10 mg kg^{-1} calcium chloride and tomato sauce canning mediums. The results indicated that the degree of clumping of canned bean increased as the moisture content decreased among the varieties (r =-0.981, P < 0.01) when beans were canned in brine solution. The result also revealed that the increased protein content will result in increased PWDWT (r = 0.916, P<0.05).

A significant correlation was found between crude protein and PWDWT (r = 0.917, P<0.05) for beans canned in brine solution together with 10 mg kg^{-1} $CaCl_2$ which entailed the increased crude protein in common bean varieties may increase the PWDWT. The calcium composition had negative correlation with PWDWT, splits, degree of clumping and visual appearance. This result agreed with Occeńa *et al*. (1992) study on correlation between chemical composition and canning quality attributes of common bean (*Phaseolus Vulgaris L.)*. Moisture content was strongly correlated with starchiness of the tomato sauce canned bean product (r = 0.977, P<0.01). As the moisture content increased in bean varieties, the starchiness of the canned bean product definitely increases due to the increased moisture content which might result burst of seed coat leads to starchiness. Crude protein was positively correlated with visual appearance and degree of clumping accordingly.

3.9. Correlation Matrix between Physico-Chemical Properties and Canning Quality Attributes of Common Beans

The correlation matrix results in this study can be used as valuable information for bean breeder in the Ethiopian context. These relations can be used to predict the canning quality of early generation genotypes. Table 13 reveals the correlation of physico-chemical properties and canning quality attributes of beans canned in three different canning mediums such as brine solution, brine solution together with 10 mg kg^{-1} of $CaCl_2$ and tomato sauce. The results indicate there is a significant (P < 0.05) negative correlation between hydration capacity and hydration coefficient (r = -0.898); and there is also significantly (P < 0.05) negative correlation between swelling capacity and hydration coefficient (r = -0.896) for beans canned in tomato sauce.

Hydration capacity and hydration coefficient had a significant negative correlation (r = -0.898, P<0.05) for beans canned in brine solution. Swelling capacity and hydration coefficient had also string negative correlation (r = -0.896, P< 0.05). Correlation between hydration and swelling capacities with hydration coefficient was negatively significant for beans canned in brine solution together with 10 mg kg^{-1}calcium chloride. Cooking time had for the most part negative correlation with significant correlation in most canning quality attributes.

3.10. Sensory Characteristics of Canned Common Bean Products

Sensory score of common bean varieties canned in brine solution, 10 mg $kg^{-1}$of calcium chloride with brine solution and tomato sauce are presented in Table 14. Sensory characteristics were performed by six sensory panelists on nine hedonic scales. The preference of panelists is Awash Melka bean variety in all sensory attributes when bean varieties were canned in brine solution. According to sensory quality attributes, Awash Melka scored like extremely. The least sensory score was observed in Chercher due to high splits which in turn resulted in poor appearance and less acceptability by panelists. Generally, all sensory attribute scores show significant difference (P < 0.05) across each variety for common bean varieties canned in brine solution.

Sensory score of common bean canned in brine solution together with 10 mg $kg^{-1}$of calcium chloride was also presented in Table 14. Based on sensory score results, it was showed that Awash Melka bean variety got high acceptance by scoring extremely like in all sensory quality attributes. Chercher and Omer bean varieties had minimum sensory scores. The Chercher bean variety had minimum score because of its high splitness when compared to other bean varieties and Omer bean variety because of its large size which in turn has an effect on consumer acceptance. Additional reason for Omer bean variety to have minimum sensory score is that small number of seeds can fill the entire can. Consumers prefer more beans canned in a single can. All score are significantly different ($P < 0.05$) across each variety.

In many parts of the world common beans are canned in tomato sauce and are commercially available as "baked beans" (Van der Merwe, 2006). In Table 14, sensory score of common bean varieties canned in tomato sauce was presented. The average overall acceptability results of taste evaluation by panelists for Awash-1, Awash Melka, Chercher, Argene and Omer were 7.8 (like very much), 7.0 (like moderately), 7.0 (like moderately), 6.4 (like slightly) and 8.0 (like very much) respectively. According to sensory panelists Awash-1 bean variety is of good sensory quality in all sensory attributes when it is canned with tomato sauce. This is may be because the small seed size and round shape gave good appearance to impress sensory panelists.

Table 12. Correlation matrix between chemical composition and canning quality attributes of common beans.

	Beans canned in brine solution				Beans canned in brine solution with 10 mg kg^{-1} $CaCl_2$				Beans canned in tomato sauce			
	Moisture content	Crude protein	Total ash	Ca	Moisture content	Crude protein	Total ash	Ca	Moisture content	Crude protein	Total ash	Ca
Hydration coefficient	0.721	-0.084	0.133	0.408	0.718	-0.078	0.184	0.382	0.721	-0.084	0.133	0.408
PWDWT	-0.851	0.916*	-0.566	-0.324	-0.831	0.917*	-0.575	-0.315	-0.170	0.546	-0.395	-0.093
Visual appearance	-0.930*	0.740	-0.434	-0.334	-0.918*	0.798	-0.410	-0.438	-0.926*	0.923*	-0.660	-0.231
Splits	-0.898*	0.707	-0.415	-0.282	-0.893*	0.694	-0.267	-0.573	-0.893*	0.570	-0.421	-0.225
Degree of clumping	-0.981**	0.722	-0.475	-0.486	-0.938*	0.594	-0.343	-0.625	-0.945*	0.906*	-0.705	-0.212
Starchiness	0.960*	-0.760	-0.544	0.247	0.920*	-0.691	0.299	0.560	0.977**	-0.662	0.456	0.512
Flavor and taste	-0.833	0.913*	-0.538	-0.201	-0.219	0.681	-0.193	-0.192	-0.547	0.046	-0.429	-0.076
Seed size	-0.896*	0.914*	-0.726	-0.022	-0.845	0.892*	-0.488	-0.287	-0.924*	0.789	-0.833	0.002

** Correlation is significant at 0.05 level; ** Correlation is significant at 0.01 level.*

Table 13. Correlation matrix between physico-chemical properties and canning quality attributes of common beans.

	Beans canned in brine solution			Beans canned in brine solution with 10 mg kg^{-1} $CaCl_2$			Beans canned in tomato sauce		
	Hydration capacity	Swelling capacity	Cooking time	Hydration capacity	Swelling capacity	Cooking time	Hydration capacity	Swelling capacity	Cooking time
Hydration coefficient	-0.898*	-0.896*	0.597	-0.861	-0.858	0.540	-0.898*	-0.896*	0.597
PWDWT	-0.059	-0.048	-0.295	-0.106	-0.095	-0.265	-0.719	-0.703	0.214
Visual appearance	0.421	0.424	-0.501	0.274	0.283	-0.525	-0.053	0.058	-0.254
Splits	0.454	0.455	-0.482	0.369	0.382	-0.658	0.618	0.613	-0.463
Degree of clumping	0.358	0.367	-0.524	0.419	0.433	-0.626	0.081	0.085	-0.232
Starchiness	-0.412	-0.412	0.410	-0.402	-0.414	0.649	-0.404	-0.414	0.539
Flavor and taste	0.050	0.055	-0.293	-0.592	-0.575	-0.051	0.518	0.510	-0.097
Seed size	0.121	0.118	-0.146	0.078	0.086	-0.364	0.192	0.186	-0.060

** Correlation is significant at 0.05 level; ** Correlation is significant at 0.01 level.*

Table 14: Sensory quality evaluation of canned common bean products.

	Beans canned in brine solution				Beans canned in brine solution with10 mg kg^{-1} $CaCl_2$				Beans canned in tomato sauce			
Varieties	Color	Appearance	Taste	Overall acceptability	Color	Appearance	Taste	Overall acceptability	Color	Appearance	Taste	Overall acceptability
Awash-1	7.4 ± 0.89^{ab}	5.8 ± 1.09^{bc}	7.6 ± 0.54^{ab}	7.2 ± 0.84^{b}	8.0 ± 0.00^{a}	7.8 ± 0.83^{b}	7.6 ± 0.55^{ab}	8.0 ± 0.71^{ab}	8.0 ± 0.71^{a}	8.0 ± 0.70^{a}	8.0 ± 1.20^{a}	7.8 ± 1.09^{ab}
Awash melka	8.2 ± 0.45^{a}	8.6 ± 0.55^{a}	8.2 ± 0.45^{a}	8.6 ± 0.55^{a}	8.4 ± 0.55^{a}	9.0 ± 0.00^{a}	8.0 ± 0.00^{a}	8.6 ± 0.55^{a}	7.8 ± 0.84^{ab}	7.8 ± 1.64^{ab}	7.2 ± 1.30^{a}	7.0 ± 2.35^{b}
Chercher	6.2 ± 1.30^{b}	5.0 ± 1.22^{c}	6.4 ± 0.55^{c}	6.2 ± 0.84^{b}	6.8 ± 0.84^{b}	6.4 ± 0.89^{cd}	7.0 ± 0.71^{b}	6.6 ± 0.71^{c}	7.2 ± 0.45^{bc}	6.8 ± 0.45^{b}	6.8 ± 1.78^{bc}	7.0 ± 1.22^{b}
Argene	6.6 ± 1.52^{b}	6.6 ± 1.52^{b}	6.6 ± 1.34^{bc}	6.6 ± 0.89^{b}	7.2 ± 0.45^{b}	7.2 ± 0.45^{bc}	7.0 ± 0.71^{b}	7.4 ± 0.89^{bc}	7.6 ± 1.14^{b}	6.6 ± 0.55^{b}	6.6 ± 1.52^{c}	6.4 ± 1.94^{c}
Omer	7.0 ± 1.00^{ab}	7.0 ± 1.22^{b}	6.8 ± 0.84^{bc}	7.0 ± 0.71^{b}	6.8 ± 0.45^{b}	5.8 ± 0.45^{d}	7.0 ± 0.00^{b}	6.6 ± 0.84^{c}	7.6 ± 0.89^{b}	7.6 ± 0.89^{ab}	8.2 ± 0.84^{a}	8.0 ± 0.71^{a}

Means within same column followed by the same letters are not significantly different ($P > 0.05$). All values are mean ± SD of three independent determinations.

4. Conclusions

The canning qualities of common bean varieties have been studied using different canning mediums. Awash Melka bean variety had the best canning quality when canned in brine solution and 10 mg kg^{-1} calcium chloride with brine solution. Awash Melka and Awash-1 bean varieties revealed that the percentage washed drained weight was greater than 60% when canned in brine solution, which satisfies the export standards for canned beans. During canning quality evaluation of bean varieties canned in tomato sauce, Awash-1 and Awash Melka showed superior results in all canning quality parameters. These two bean varieties are currently exported to an international market due to their acceptability in canning quality. Argene bean variety showed promising results in all canning quality parameters. However, Chercher bean variety was not good enough for canning purpose due to its inferiority in all respective canning quality parameters. Similarly, Omer bean variety is not acceptable for canning purpose due to its large seed size.

Finally, the canning quality evaluation results revealed that Awash-1, Awash Melka and Argene bean varieties were suitable for canning, and have the potential to be used as a raw material for the bean canning industry. Commercial type common beans should get great emphasis by different stakeholders in the bean value chain to provide an international market for canning purpose.

By and large, the results of canning quality evaluation indicated that there are potential bean varieties of high canning quality in East Africa with diverse agro-ecological zones suitable for bean production. As a result, private sectors, research institutes, policy makers and commercial bean producers of the Great Lakes Region of Africa should establish and strengthen food/bean research institutes for canning quality evaluation. Furthermore, value added product design and development of beans via opening of local canning industries in the sub Saharan Region can boost the export potential of end products and import substitution through resource maximization. Ethiopia and other African bean producing countries should refrain from sending their genetically potential bean varieties/cultivars for canning quality evaluation purpose to other countries which are obtained from agricultural research institutes and Universities. It is recommended to utilize wisely the potential bean cultivars with diverse agro-climatic zones of the region through nation-wide skill and knowledge, capacity and investment development.

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