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Canning Quality of New Drought-Tolerant Dry Bean (*Phaseolus vulgaris* L.) Lines

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ABSTRACT

Canning quality of twenty nine new drought-tolerant bean lines from two grain types; large-seeded and small-seeded, was investigated. Bean seeds were soaked, blanched, canned in brine and stored for three weeks prior to evaluation. Mex-142, the popular canning variety, was used as a control. The traits studied were Hydration Coefficient (HC), Washed Drained Weight (WDWT), Percentage Washed Drained Weight (PWDWT), firmness, splits, clumping, size, shape and uniformity. Except for PWDT in large-seeded genotypes, there were significant differences between lines ($p<0.05$) for all traits studied. Small-seeded genotypes had higher HC (1.75) compared to large seeded genotypes (1.56). Seven small-seeded genotypes had HC >1.7 as required by processors. The highest WDWT was recorded in BCB11-10 (294.4±0.67 g) and BCB11-176 (294.1±0.97 g). All genotypes had PWDWT >60% as desired by processors. The control, Mex-142 had high splits (3.0) and low uniformity (3.67±0.67). The results showed that the small-seeded genotypes BCB11-80, BCB11-98 and BCB11-108 had better canning quality than Mex-142. Large-seeded genotypes require longer soaking and blanching period to meet the industry standards for HC.

Key words: Dry bean, canning quality, hydration coefficient

INTRODUCTION

Canned bean products are convenient, have a distinctive colour and provide excellent consumer value (Uebersax, 2006). In urban areas of Africa, canned beans are an important form of dry bean consumption (Siddiq and Uebersax, 2012) and because of the high costs of cooking fuels and electricity and the current preference for off-shelf products, demand for canned beans is expected to increase. However, in Kenya, the bean processing industry mainly depends on a single variety, Mex-142 which is a small-seeded white navy bean that was released in the 1960s (Leakey, 1970). According to McCartney (1966), selection of this variety for canning was based on a limited number of quality attributes. In addition, Kimani *et al.* (2005) reported that Mex-142 is susceptible to diseases and droughts. Currently, due to insufficient local supply of raw material, bean processors in Kenya are obliged to import raw materials from neighboring Ethiopia which increases the production cost of the canned beans. In addition, to cope with the diverse consumer preferences for canned beans in the country, processors have established production lines for canned beans of other bean types such as large-seeded red kidney and small red. This necessitates development of new varieties of these other types that are suited to local environments, in combination with good quality attributes to meet the requirements of the canning industry.

Bean varieties destined for the canning industry should meet the specific standards that are rigorously followed by this industry regardless of their yield potential. According to Hosfield *et al.* (2000), more than 16 traits contribute to canning quality of dry beans. Processors require beans that are easy to cook, efficient to process and that deliver high processor yields (Walters *et al.*, 1997). Traits related to the hydration capacity of the beans are important to processors as these relate to canning yield (Van Loggerenberg, 2004; Ghaderi *et al.*, 1984). The texture of cooked beans has been found to correlate with consumer acceptability (Mkanda, 2007). Physical properties such as splits, size, shape and uniformity have been suggested to be important criteria in the evaluation of canning quality of dry beans (Uebersax and Hosfield, 1985). Significant genetic variation in canning quality attributes has been reported in dry beans (Van Loggerenberg, 2004; Gathu *et al.*, 2012; Walters *et al.*, 1997; Balasubramanian *et al.*, 2000). Thus, dry bean lines must be evaluated for several attributes before being released as improved varieties for canning.

The University of Nairobi Bean Research Program has identified new bean lines of different market classes with good agronomic traits such as disease resistance and drought tolerance. However, the suitability of these lines for the canning industry has not been investigated. The objective of this study was to determine canning quality of these new lines in order to identify bean varieties that meet the requirements of the bean processing industry in Kenya.

MATERIALS AND METHODS

Materials: Twenty-nine advanced bean lines of different market classes and the check variety Mex-142 were used in the study. The advanced lines consisted of seven market classes that embrace two grain types; large-seeded and small-seeded. There were four large-seeded market classes: Red mottled (BCB11-130, BCB11-142, BCB11-144, BCB11-145 and BCB11-324); Red kidney (BCB11-158, BCB11-159, BCB11-162, BCB11-176 and BCB11-327); Speckled sugar (BCB11-507, BCB11-303, BCB11-386, BCB11-467, BCB11-204) and Yellow (BCB11-488) and three small-seeded market classes: Navy bean (BCB11-10, BCB11-108, BCB11-48, BCB11-62, BCB11-80 and BCB11-98); Small red (BCB11-182, BCB11-184, BCB11-202, BCB11-245 and BCB11-344); and Pinto (BCB11-512 and BCB11-515). The control variety, Mex-142 is a small-seeded white Navy bean.

Methods

Sample preparation: Bean samples were manually cleaned for any foreign materials and damaged seeds. Initial Moisture Content (MC) was determined by taking duplicate 10 g samples from each line and oven-dried at 100°C for 48 h. Then, MC (%) was calculated as follows:

$$\text{MC}(\%)=\frac{\text{Mass of fresh bean (g)} - \text{Mass of dried bean (g)}}{\text{Mass of fresh bean (g)}}\times 100$$

Based on MC (%), 100 g bean seed solids required to fill each can were calculated (Uebersax and Hosfield, 1985) as follows:

$$\text{Fresh weight to yield required solids} = \frac{\text{Solids required}}{\text{Solids at a given moisture}}$$

Bean canning process: Triplicate bean samples of each line with weights equivalent to 100 g solids were accurately weighed, placed into mesh bags, soaked in water for 30 min at room temperature and then blanched for 30 min at 78°C in water containing ≈100 ppm of Ca^{++} (Uebersax and Hosfield, 1985). The samples were first drained and after weighing, transferred into coded (73×110 mm) cans and covered with boiling brine containing 100 ppm Ca^{++}, 1.3% NaCl and 1.56% sugar. The cans were sealed with automatic can seamer (Sanitary Can Machine Co., Los Angeles, CA, USA) and cooked in an automatic retort (Barriquand Steriflow, Roanne, France) at 115.6°C for 45 min followed by instant cooling. The cans of processed beans were stored for three weeks prior to opening for evaluation of canning-quality traits (Uebersax and Hosfield, 1985).

Canning quality evaluation

Hydration Coeficient (HC): The weight gained by imbibition during soaking and blanching was used to calculate the hydration coefficient (Van Der Merwe *et al.*, 2006) as follows:

$$\text{HC} = \frac{\text{Mass of soaked beans (g)}}{\text{Mass of dry beans (g)}}$$

Washed Drained Weight (WDWT) and Percentage Washed Drained Weight (PWDWT): WDWT was determined on rinsed beans drained for 2 min on a number 8 mesh (0.239 cm) screen positioned at 15° angle (Uebersax and Hosfield, 1985). PWDWT was calculated as follows (Van Der Merwe *et al.*, 2006):

$$\text{PWDWT} = \frac{\text{Washed drained weight (g)}}{\text{Mass of can contents (g)}} \times 100$$

Firmness: The texture of processed beans was determined by using a Texture Analyzer TA-XT.PLUS (Stable Micro Systems, Surrey, UK) equipped with a heavy duty platform (HDP/90). A penetration force was applied to 18 individual seeds of processed beans that were randomly selected from the triplicate samples of each line. The operating condition was; pre-test speed (1.5 mm s^{-1}), test speed (2.0 mm s^{-1}), post-test speed (10 mm s^{-1}), trigger force (5 g) and distance (15 mm). This test was repeated five times on each line.

Visual evaluation: During draining and rinsing of the processed beans, appearance and physical traits were studied using a seven-point hedonic scale (Uebersax and Hosfield, 1985). The traits investigated were; splits (1 indicates very broken and 7 very intact), clumping (1 indicates very much clumping and 7 very little clumping), size (1 indicates very small and 7 very large), shape (1 indicates very elongated and 7 very round) and uniformity (1 indicates very variable and 7 indicate very uniform).

Statical analysis: All data was statistically analyzed using a completely randomized analysis of variance in GenStat, V.13, (VSN International, 2010). Significant differences were determined at the $p<0.05$ level and Duncan's Multiple Range Test was used for mean separation where differences were obtained.

RESULTS AND DISCUSSION

Canning quality traits showed significant ($p<0.05$) differences in both large (Table 1) and small (Table 2) seeded genotypes. Hydration Coefficient (HC) differed significantly ($p<0.05$) among large and small-seeded genotypes. Among the large-seeded genotypes, BCB11-507 had the highest HC (1.63) and BCB11-145 the lowest (1.43). Mex-142, the check variety, had a higher HC than all large-seeded genotypes (1.74). The HC of the small-seeded genotypes ranged from 1.35-2.13, four lines had significantly ($p<0.05$) higher HC than Mex-142. In general, genotypes of navy bean market class showed higher HC than genotypes from other market classes. The hydration coefficient is an important criterion for bean processors, if HC is low, a larger quantity of beans is

Table 1: Canning quality traits of large-seeded genotypes

Line	HC	WDWT (g)	PWDWT (%)	Firmness (N)	Splits	Clumping	Size	Shape	Uniformity
BCB11-130	1.55 ± 0.01^{cd}	284.0 ± 1.03^{cd}	69.0 ± 1.08^{ab}	11.35 ± 0.94^{f}	5.67 ± 0.33^{e}	5.67 ± 0.33^{ab}	5.33 ± 0.33^{bcd}	4.00 ± 0.58^{cd}	6.00 ± 0.00^{d}
BCB11-142	1.49 ± 0.02^{b}	284.3 ± 0.91^{cd}	69.4 ± 1.84^{ab}	$9.35\pm1.15d^{ef}$	$5.00\pm0.56d^{e}$	6.00 ± 0.56^{ab}	4.67 ± 0.33^{b}	4.67 ± 0.33^{d}	5.00 ± 0.00^{bcd}
BCB11-144	1.55 ± 0.02^{cde}	279.6 ± 0.54^{abc}	65.6 ± 0.88^{ab}	10.24 ± 0.71^{ef}	4.33 ± 0.67^{cde}	6.00 ± 0.56^{ab}	5.00 ± 0.00^{bc}	3.33 ± 0.33^{bc}	5.33 ± 0.33^{cd}
BCB11-145	1.43 ± 0.01^{a}	285.6 ± 0.68^{d}	68.8 ± 0.12^{ab}	6.76 ± 0.55^{abcd}	4.00 ± 0.56^{bcd}	5.33 ± 0.33^{ab}	5.00 ± 0.00^{bc}	3.00 ± 0.00^{abc}	4.00 ± 0.58^{bc}
BCB11-158	1.52 ± 0.06^{bc}	279.9 ± 2.65^{bc}	67.6 ± 0.90^{ab}	9.90 ± 1.16^{ef}	4.00 ± 0.56^{bcd}	5.67 ± 0.67^{ab}	5.33 ± 0.67^{bcd}	3.33 ± 0.33^{bc}	4.00 ± 0.58^{abc}
BCB11-159	1.52 ± 0.01^{bc}	$279.1\pm1.2ab^{c}$	67.5 ± 0.82^{ab}	8.86 ± 1.05^{cde}	3.00 ± 0.00^{abc}	5.67 ± 0.33^{ab}	6.33 ± 0.33^{d}	2.00 ± 0.58^{a}	2.68 ± 0.33^{a}
BCB11-162	1.58 ± 0.01^{def}	284.2 ± 2.62^{cd}	68.2 ± 1.77^{ab}	8.40 ± 0.78^{bcde}	5.00 ± 0.56^{de}	5.00 ± 1.00^{ab}	6.00 ± 0.00^{cd}	2.67 ± 0.00^{ab}	5.00 ± 0.00^{bcd}
BCB11-176	1.57 ± 0.01^{cdef}	294.1 ± 0.97^{e}	70.9 ± 0.13^{ab}	6.08 ± 0.43^{ab}	2.67 ± 0.33^{ab}	5.33 ± 0.33^{ab}	5.00 ± 0.58^{bc}	2.33 ± 2.33^{ab}	5.00 ± 0.58^{bcd}
BCB11-204	1.43 ± 0.00^{a}	278.7 ± 1.47^{abc}	71.6 ± 5.19^{b}	8.37 ± 1.16^{bcde}	4.00 ± 0.56^{bcd}	4.33 ± 0.67^{a}	5.33 ± 0.33^{bcd}	3.00 ± 0.00^{abc}	5.00 ± 0.58^{bcd}
BCB11 -303	1.43 ± 0.00^{ef}	274.3 ± 1.88^{a}	67.0 ± 0.46^{ab}	9.76 ± 0.27^{ef}	3.00 ± 0.56^{abc}	6.00 ± 0.00^{ab}	5.33 ± 0.33^{bcd}	3.00 ± 0.00^{abc}	5.67 ± 0.33^{d}
BCB11-324	1.55 ± 0.00^{cd}	290.5 ± 1.68^{e}	70.0 ± 0.26^{ab}	9.20 ± 0.46^{cdef}	5.33 ± 0.33^{de}	5.67 ± 0.33^{ab}	5.33 ± 0.33^{bcd}	3.00 ± 0.00^{abc}	5.33 ± 0.33^{cd}
BCB11-327	1.62 ± 0.01^{ef}	291.9 ± 1.96^{e}	70.5 ± 1.24^{ab}	6.83 ± 0.54^{abcd}	5.67 ± 0.33^{e}	6.33 ± 0.33^{b}	5.00 ± 0.00^{bc}	4.67 ± 0.33^{d}	6.00 ± 0.00^{d}
BCB11- 386	1.62 ± 0.01^{ef}	281.1 ± 1.05^{bcd}	67.2 ± 0.76^{ab}	5.62 ± 1.04^{a}	$5.00\pm0.00d^{e}$	6.00 ± 0.56^{ab}	5.00 ± 0.00^{bc}	2.67 ± 0.33^{ab}	5.67 ± 0.67^{d}
BCB11-467	1.56 ± 0.01^{cd}	282.5 ± 0.53^{bcd}	65.1 ± 0.40^{a}	6.83 ± 0.63^{abcd}	2.00 ± 0.56^{a}	5.00 ± 0.00^{ab}	6.00 ± 0.00^{cd}	2.00 ± 0.00^{a}	4.67 ± 0.33^{bcd}
BCB11-488	1.56 ± 0.01^{cd}	277.0 ± 1.23^{ab}	67.6 ± 0.49^{ab}	11.12 ± 0.70^{f}	5.00 ± 0.56^{de}	5.67 ± 0.33^{ab}	6.00 ± 0.58^{cd}	2.67 ± 0.67^{ab}	6.00 ± 0.00^{d}
BCB11- 507	1.63 ± 0.01^{f}	274.4 ± 2.20^{a}	67.8 ± 3.86^{ab}	9.72 ± 0.89^{ef}	4.00 ± 0.56^{bcd}	6.00 ± 0.56^{ab}	5.33 ± 0.33^{bcd}	3.00 ± 0.58^{abc}	5.00 ± 0.00^{bcd}
Mex-142	1.74 ± 0.01^{g}	282.8 ± 2.85^{cd}	69.7 ± 1.38^{ab}	6.56 ± 0.64^{abc}	3.00 ± 0.00^{abc}	5.33 ± 0.33^{ab}	2.67 ± 0.33^{a}	5.00 ± 0.00^{d}	3.67 ± 0.67^{ab}
Mean	1.56	282.6	68.44	8.53	4.16	5.59	5.22	3.20	4.94
CV %	1.90	1.0	4.6	21.4	19.9	15.2	11.4	18.1	15.0

Table 2: Canning quality traits of small-seeded genotypes

Line	HC	WDWT (g)	PWDWT (%)	Firmness (N)	Splits	Clumping	Size	Shape	Uniformity
BCB11-10	1.70 ± 0.01^{d}	294.4 ± 0.67^{d}	71.13 ± 0.96^{d}	8.17 ± 0.77^{abcd}	2.33 ± 0.33^{a}	6.67 ± 0.67^{cd}	2.67 ± 0.33^{abcd}	2.67 ± 0.33^{a}	4.67 ± 0.88^{ab}
BCB11-48	1.64 ± 0.01^{c}	267.1 ± 0.81^{a}	64.77 ± 1.28^{ab}	7.96 ± 1.07^{abc}	2.33 ± 0.33^{a}	5.67 ± 0.67^{cd}	2.67 ± 0.33^{abcd}	5.00 ± 0.00^{bc}	4.67 ± 0.33^{ab}
BCB11-62	1.78 ± 0.01^{e}	273.6 ± 1.53^{ab}	67.83 ± 1.96^{bcd}	7.96 ± 0.46^{ab}	3.33 ± 0.33^{ab}	6.00 ± 0.00^{d}	$3.67\pm0.33\ ^{d}$	5.33 ± 0.33^{bcd}	5.00 ± 0.00^{bc}
BCB11-80	1.92 ± 0.00^{f}	272.4 ± 1.43^{ab}	66.00 ± 0.57^{bc}	8.29 ± 0.73^{abcd}	5.67 ± 0.33^{c}	6.33 ± 0.33^{d}	2.33 ± 0.33^{abc}	4.67 ± 0.33^{b}	6.33 ± 0.33^{de}
BCB11-98	1.98 ± 0.01^{g}	282.2 ± 4.89^{c}	66.23 ± 0.77^{bc}	9.51 ± 0.34^{bcd}	5.67 ± 0.33^{c}	6.33 ± 0.33^{b}	3.00 ± 0.00^{bcd}	3.00 ± 0.00^{a}	5.67 ± 0.33^{bcde}
BCB11-108	1.99 ± 0.01^{g}	277.2 ± 1.94^{bc}	63.37 ± 2.53^{ab}	10.75 ± 0.97^{de}	5.67 ± 0.33^{c}	6.00 ± 0.00^{d}	3.00 ± 0.00^{bcd}	3.00 ± 0.00^{a}	6.00 ± 0.00^{cde}
BCB11-182	1.75 ± 0.00^{e}	265.6 ± 0.58^{a}	63.33 ± 0.81^{ab}	10.17 ± 0.92^{bcde}	4.00 ± 0.58^{b}	5.00 ± 0.00^{bcd}	1.67 ± 0.33^{a}	6.00 ± 0.00^{de}	6.00 ± 0.00^{cde}
BCB11-184	2.13 ± 0.00^{h}	269.1 ± 1.85^{ab}	65.13 ± 1.79^{ab}	6.67 ± 0.72^{a}	3.00 ± 0.00^{ab}	4.33 ± 0.67^{bc}	1.67 ± 0.33^{a}	5.33 ± 0.33^{bcd}	6.33 ± 0.33^{de}
BCB11-202	1.59 ± 0.04^{b}	276.6 ± 4.29^{bc}	67.13 ± 0.29^{bcd}	10.57 ± 0.92^{bde}	2.67 ± 0.33^{a}	3.67 ± 0.67^{ab}	2.67 ± 0.33^{abcd}	5.67 ± 0.33^{cde}	5.33 ± 0.33^{bcd}
BCB11-245	1.35 ± 0.01^{a}	270.5 ± 3.03^{ab}	63.90 ± 0.77^{ab}	13.76 ± 0.85^{f}	6.33 ± 0.33^{c}	5.33 ± 0.33^{cd}	1.67 ± 0.33^{a}	6.33 ± 0.33^{e}	6.67 ± 0.33^{e}
BCB11-344	1.58 ± 0.02^{b}	269.0 ± 3.68^{ab}	64.80 ± 2.07^{ab}	14.55 ± 0.93^{f}	5.33 ± 0.33^{c}	4.33 ± 0.67^{bc}	1.67 ± 0.33^{a}	6.00 ± 0.00	6.00 ± 0.00^{cde}
BCB11-512	1.69 ± 0.00^{d}	265.3 ± 1.23^{a}	61.20 ± 0.30^{a}	9.63 ± 0.47^{bcd}	5.33 ± 0.33^{c}	6.00 ± 0.00^{d}	3.33 ± 0.67^{cd}	5.33 ± 0.33^{bcd}	6.33 ± 0.33^{de}
BCB11-515	1.62 ± 0.00^{bc}	272.7 ± 2.85^{ab}	65.40 ± 1.12^{abc}	12.38 ± 1.00^{ef}	5.67 ± 0.33^{c}	2.67 ± 0.33^{a}	2.00 ± 0.00^{ab}	6.33 ± 0.33^{e}	6.67 ± 0.33^{e}
Mex-142	1.74 ± 0.01^{e}	282.8 ± 2.85^{c}	69.67 ± 1.38^{cd}	6.56 ± 0.64^{a}	3.00 ± 0.00^{ab}	5.33 ± 0.33^{cd}	2.67 ± 0.33^{abcd}	5.00 ± 0.00^{bc}	3.67 ± 0.67^{a}
Mean	1.75	274.2	65.71	9.78	4.33	5.19	2.48	4.98	5.67
CV %	1.30	1.7	3.6	18.3	13.8	14.9	23.3	8.8	11.9

necessary to fill a given can volume. Thus, a higher HC is associated with improved canning yield (Ghaderi *et al.*, 1984). According to Balasubramanian *et al.* (2000), an HC of 1.8-2.0 is considered optimum by the industry and is indicative of well-soaked beans. The HC values of the small-seeded genotypes are comparable to those reported previously (Hosfield and Uebersax, 1980; Mekonnen, 2012). The generally lower HC of the large-compared to small-seeded genotypes, may be attributed to inherent differences in permeability to water associated with seed size. Del Valle *et al.* (1992) found that seed coats of the large-seeded red beans displayed the lowest rate of water uptake compared to small-seeded white, black and red beans. These differences have implications for the canning process, as a longer soaking or blanching period is needed for large seeded beans. Current procedures for laboratory evaluation of canning quality of beans (Uebersax and Hosfield, 1985; Balasubramanian *et al.*, 2000; Van Loggerenberg, 2004; Van Der Merwe *et al.*, 2006) were developed for markets dominated by the small seeded navy beans, such as in the USA and South Africa. These HC results suggest that differences in seed size should be taken into consideration during laboratory evaluation of canning quality of beans.

Differences were significant for WDWT ($p<0.05$) but not for PWDWT ($p>0.05$) among the large seeded genotypes (Table 1), BCB11-176 (294.1 g) had the highest WDWT and BCB11-303 (274.3 g) the lowest. Small-seeded genotypes differed significantly ($p<0.05$) in WDWT, BCB11-10 had the highest WDWT (294.4 g) and BCB11-512 the lowest (265.3 g) and in PWDWT; BCB11-10 (71.13%) had the highest and BCB11-512 the lowest (61.2%) (Table 2). Thus, in spite of their lower HC, large-seeded genotypes had higher mean WDWT and PWDWT than small seeded genotypes. This indicates that low HC led to more water uptake inside the can during the storage period of the canned beans. According to Van Loggerenberg (2004), beans seeds should achieve 80% weight increase before can-filling. This can be achieved by prolonging the soaking and blanching period until the desired HC is attained, thus avoiding excessive water uptake in the can. Based on existing canning standards, all genotypes evaluated in this study met the desired 60% PWDWT (Balasubramanian *et al.*, 2000).

Firmness of the processed beans differed significantly ($p<0.05$) in both large and small-seeded genotypes. Among large seeded genotypes, the highest firmness was recorded on BCB11-130 (11.35 N) and the lowest on BCB11-386 (5.62 N). The firmness among small-seeded genotypes ranged from 14.55 N in BCB11-344 to 6.67 N in BCB11-184 with grand mean of 9.78 N. Mex-142 had firmness of 6.6 N. Differences were significant ($p<0.05$) among large-seeded genotypes for splits and the genotype BCB11-467 had the most broken seeds with score of 2.0 while BCB11-130 and BCB11-327 were the most intact, each with a score of 5.67. Splits also differed significantly ($p<0.05$) among small-seeded genotypes with the most broken seeds being recorded in BCB11-10 and BCB11-48, each with 2.33. The most intact small-seeded genotype was BCB11-245 (6.33). Mex-142 had a score of 3.33. Texture (firmness) is used as an indication of the degree of consumer acceptance of canned beans as it affects the perceived stimulus of chewing (Ghaderi *et al.*, 1984). Consumers would prefer the bean to be soft but with fewer splits. However, soft texture is associated with seed breakdown (De Lange and Labuschagne, 2001; Van Loggerenberg, 2004). Clumping differed significantly ($p<0.05$) among genotypes of both grain types. Line BCB11-515 was the most clumping genotype with score of 2.67. Clumping of individual beans can be attributed to starch exudation into the canning medium (Van Loggerenberg, 2004) and indicates poor canning quality.

Significant ($p<0.05$) variation in size and shape was observed in both groups. Overall, seeds of most large seeded genotypes were large and elongated while small-seeded genotypes had small and rounded seeds. Beans destined for canning purposes should be uniform in size and with regular shape. Visual evaluation of bean uniformity in color and size showed significant ($p<0.05$) differences among genotypes. Across all genotypes, BCB11-159 (2.68) and the control variety, Mex-142 (3.67) were the least uniform. The poor uniformity of Mex-142 may indicate varietal purity deterioration since the variety has been grown since 1960s (Leakey, 1970). Furthermore, these results explain the frequent complaints by the processing industry on the purity of existing canning beans and subsequent costs of the manual cleaning of beans before the canning process.

CONCLUSION

Nearly, 50 years after Mex-142 was released as the preferred canning bean variety in eastern Africa, this study was the first attempt to evaluate new lines of dry bean genotypes for their suitability for the canning industry in Kenya. According to McCartney (1966), only soakability and hard-shell defect tests were used in the past to screen for canning quality. This study identified three small-seeded, navy bean genotypes; BCB11-80, BCB11-98 and BCB11-108 that combined good canning quality traits and which were better than the control variety, Mex-142. This study also revealed that canning quality of large-seeded bean genotypes can be improved by increasing the soaking or blanching period prior to the canning process.

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REFERENCES

Balasubramanian, P., A. Slinkard, R. Tyler and A. Vandenberg, 2000. A modified laboratory canning protocol for quality evaluation of dry bean (*Phaseolus vulgaris* L). J. Sci. Food Agric., 80: 732-738.

De Lange, A. and M. Labuschagne, 2001. Multivariate assessment of canning quality, chemical characteristics and yield of small white canning beans (*Phaseolus vulgaris* L) in South Africa. J. Sci. Food Agric., 81: 30-35.

Del Valle, J.M., D.W. Stanley and M.C. Bourne, 1992. Water absorption and swelling in dry bean seeds. J. Food Processing and Preserv., 16: 75-98.

Gathu, E.W., E.G. Karuri and P.M.K. Njage, 2012. Physical characterization of new advanced drought tolerant common bean (*Phaseolus vulgaris*) lines for canning quality. Am. J. Food Technol., 7: 22-28.

Ghaderi, A., G.L. Hosfield, M.W. Adams and M.A. Uebersax, 1984. Variability in culinary quality, component interrelationships and breeding implications in navy and pinto beans. J. Am. Soc. Hortic. Sci., 109: 85-90.

Hosfield, G.L. and M.A. Uebersax, 1980. Variability in physio-chemical properties and nutritional components of tropical and domestic dry bean germplasm. J. Am. Soc. Hortic. Sci., 105: 246-252.

Hosfield, G.L., M.A. Uebersax and L.G. Occena, 2000. Technological and genetic improvements in dry bean quality and utilization. Proceedings of the Idaho Bean Workshop, August 3-4, 2000, University of Idaho, Moscow, pp: 135-152.

Kimani, P.M., R. Buruchara, K. Ampofo, M. Pyndji, R.M. Chirwa and R. Kirkby, 2005. Breeding beans for smallholder farmers in Eastern, Central and Southern Africa: Constraints, achievements and potential. Proceedings of the PABRA Millennium Workshop, May 28-June 2, 2001, Arusha, Tanzania, pp: 11-28.

Leakey, C.L.A., 1970. The Improvement of Beans (*Phaseolus vulgaris*) in East Africa. In: Crop Improvement in East Africa, Leakey, C.L.A. (Ed.). Commonwealth Agricultural Bureaux, England, pp: 100-126.

McCartney, J.C., 1966. The selection of haricot bean varieties suitable for canning. E Afr. Agric. For. J., 32: 214-218.

Mekonnen, D., 2012. Canning quality evaluation of haricot bean (*Phaseolus vulgaris* L.) varieties grown in Ethiopia. M.Sc. Thesis, Addis Ababa Institute of Technology, Addis Ababa, Ethiopia.

Mkanda, A.V., 2007. Relating consumer preferences to sensory and physicochemical properties of dry beans (*Phaseolus vulgaris* L.). M.Sc. Thesis, University of Pretoria, South Africa.

Siddiq, M. and M.A. Uebersax, 2012. Dry Beans and Pulses Production and Consumption-an Overview. In: Dry Beans and Pulses: Production, Processing and Nutrition, Siddiq, M.A. and M.A. Uebersax (Eds.). John Wiley and Sons, USA., pp: 3-22.

Uebersax, M.A. and G.L. Hosfield, 1985. Processing quality improvement of dry edible beans: A laboratory manual for handling, processing and evaluation procedures. Michigan State University, East Lansing, USA.

Uebersax, M.A., 2006. Dry edible beans: Indigenous staple and healthy cuisine. Forum on Public Policy. http://forumonpublicpolicy.com/archive06/uebersax.pdf.

VSN International, 2010. GenStat 13th Edition. VSN International Ltd., Oxford, UK. http://www.vsni.co.uk/software/genstat.

Van Der Merwe, D., G. Osthoff and A.J. Pretorius, 2006. Comparison of the canning quality of small white beans (*Phaseolus vulgaris* L.) canned in tomato sauce by a small-scale and an industrial method. J. Sci. Food Agric., 86: 1046-1056.

Van Loggerenberg, M., 2004. Development and application of a small-scale canning procedure for the evaluation of small white beans (phaseolus vulgaris). Ph.D Thesis, University of the Free State, Bloemfontein.

Walters, K.J., G.L. Hosfield, M.A. Uebersax and J.D. Kelly, 1997. Navy bean canning quality: Correlations, heritability estimates and randomly amplified polymorphic DNA markers associated with component traits. J. Am. Soc. Hortic. Sci., 122: 338-343.