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CANNING QUALITY OF NEW GRAIN RUNNER BEAN LINES DEVELOPED IN KENYA

Abstract:
Canned beans are becoming a major form of dry bean consumption especially in urban areas of East and Central Africa for its convenience, distinctive flavor and excellent consumer value. Grain quality traits related to end-user preferences are of utmost importance for success of new grain runner bean varieties. The Legume Breeding Research and Seed Programme at the University of Nairobi recently developed several grain-type runner beanlines with different seed colours and superior agronomic traits. However, their potential for use by the processing industry is not known. The objective of this study was to evaluate the canning quality of the new breeding lines and to identify the lines that combine most of the canning quality traits. Forty-three advanced lines, three checks and one reference variety (TruFood RB) grown at Ol-Joro-Orok and Kabete Field Stations were evaluated for canning quality. The beans were soaked, blanched, canned in brine and incubated for seven days, and subsequently evaluated for canning quality attributes including hydration coefficient (HC), washed drained weight (WDWT), percentage washed drained weight (PWDWT) and texture. Physical properties (size, shape, uniformity) and visual appearance properties (splits, clumping and brine clarity) were determined subjectively using seven point hedonic scale. Results showed significant (P<0.05) differences for all traits evaluated. Thirty-five lines grown across sites met the industrial canning standards. Among the best performers at Kabete were KAB-RB13-327-92/1, KAB-RB13-326-207/1B and KAB-RB13-326-207/1B. However, the best performers among lines grown at Ol-Joro-Orok were KAB-RB13-471-117/1, SUB-OL-RB13-275-248/3 and KAB-RB13-310-161/5 suggesting a genotype x environment interaction for canning traits. The new grain runner bean lines will reduce scarcity of raw materials required by processing industries and increase the diversity of processed runner bean products.

Keywords: Canning quality, grain runner bean, hydration coefficient, genotypes

Introduction:
Grain type runner bean, (*Phaseoluscoccineus* L)also known as butter bean, is traditionally cultivated by smallholder farmers in the highlands of eastern Africa, especially in Kenya. It is grown for household consumption (Suttie, 1969; Kay, 1979)and processing by canning factories (Kimani *et al.*, 2014). Runner bean is considered to be the third economically important species of*Phaseolus* in the world (Santalla*et al.*, 2004).It is important in the United Kingdom and some parts of Europe especially Spain and Italy. Dry mature seeds are produced and consumed in Latin America, where Argentina is the leading producer (Kay, 1979). In Kenya, both dry grain and vegetable types are cultivated. The long-day vegetable types introduced from Europe are grown in parts of the Rift Valley and slopes of Mount Kenya by horticultural companies for their succulent pods. The grain type runner bean is grownin Nyandarua and Nakuru counties by smallholder farmers especially for household consumption and processing (Acland, 1970).

Grain yield of runner bean in Kenya is low (900 to 1120 kg ha^{-1}) because production is based on unimproved local landraces (Kay, 1979; Kimani *et al*, 2014). Low production of runner beans is associated with lack of improved high yielding varieties with canning characteristics demanded by the processing industry. Farmers rely on unimproved traditional varieties of runner beans such as *Nyeri*, *Kinangop 1*, *Kinangop 2*, *Dwarf 2*and *Dwarf 3*. These varieties are low yielding and susceptible to diseases compared with the new advanced breeding lines developed at the University of Nairobi (Kimani *et al.*, 2014). The low grain yield and susceptibility to diseases have led to poor adoption of the crop by farmers despite the high demand in the market.

Canned runner bean is an important product line of major canning factories in Kenya. However, due to scarcity of raw materials, factories pool their limited grain stocks for processing by one firm under contractual arrangements. Inadequate supply of raw materials is the result of limited local production, despite the growing demand. As a result, factories process runner beans seasonally, often below the installed capacities, and can hardly meet the growing market demand(TruFoods, 2014). Increasing demand for canned runner bean products is attributed to changing consumer’s preferences, urbanization and changing eating habits (TruFoods, 2014).Very little has been done to develop improved canning bean varieties in Kenya and eastern Africa in general. To our knowledge, there are no runner bean improvement programs in this region.

In 2005, the Legume Breeding Research and Seed Program of the University of Nairobi initiated a project to develop locally adapted runner bean varieties for household consumption and for the processing industries. The desired varieties should not only be acceptable to farmers, but also should meet a wide range of consumer and processor preferences.They should combinehigh yield, disease resistance withindustrial canning quality (Kimani *et al.*, 2014). To ensure the end products are acceptable to processing industries, it was necessary to collaborate with bean canning firms and farmers. The initial stages of the breeding activities involved population development and selection for yield potential, disease resistance and other agronomic traits from the segregating populations. Selected lines were subsequently evaluated for farmer preferences in on-farm participatory variety selection (PVS) and for broad adaption in on-station trials across diverse agro-ecological zones.
The objective of this study was to evaluate the canning quality of the new locally developed breeding lines and to identify the lines that combine most of the canning quality traits.

Materials and Methods:

Plant materials:

Seed samples of 47 advanced runner bean lines of which 29 were white seeded and 18 purple speckled grain types were evaluated for canning quality at Njoro Canning Factory, Njoro, Kenya. Three landraces *Nyeri*, *Dwarf 1* and *Dwarf 3,* and the industry reference variety'*TruFood RB'*were included for comparison with the new advanced breeding lines. Runner bean samples were obtained from field trials planted during 2014 cropping season at Kabete Field Station (1860 masl) andthe Kenya Agriculture and Livestock Research Organization (KARLO) Ol Joro-orokresearch station (2300 masl). Standard M1 cans (73 x 110mm) used by canning factories were obtained from local manufacturers (Tin Can Manufacturers Ltd, Nairobi, Kenya).

Sample preparation:
Bean samples equivalent to 100g of bean solids were transferred into a coded nylon mesh bags for soaking. Before the soaking, samples were separated into colour groups to avoid colour distortion during soaking process. Samples were soaked for 16 hours in cold water (25°C) followed by blanching for 15 minutes in hot water (90° C). The blanched samples were drained, weighed and transferred into M1 cans. Then seeds were covered with hot brine (90°C) with a concentration of 1.9% NaCl and sealed with an automatic can sealer (Angelus Sanitary Can Machine Co., Los Angeles, CA, USA). The sealed cans were heat sterilized in an automatic retort (BarriquandSteriflow, Roanne, France) at 122° C for 60 minutes, followed by instant water cooling. Two experts from quality control department and five technicians from Factory 5 production line provided technical support during the canning process. Each sample was replicated two times. After seven days of incubation at 38^0 C, the canned products were opened using manual can opener to assess the canning quality attributes.

Assessment of canning quality:
Canning quality of the canned runner beans was determined by procedures used at TruFood Ltd(TruFood, 2014). Data collected included fresh weight to yield required solids, hydration coefficient (HC), washed drained weight (WDWT), percent washed drained weight (PWDWT), texture, physical properties (size, shape and uniformity), and visual appearance (splits, degree of clumping and brine clarity).
Hydration coefficient (HC) is the amount of water imbibed by the seeds during soaking and blanching. It was calculated as: HC = mass of soaked beans / mass of dry beans (Loggerenberg, 2004).
The*washed drained weight*(WDWT),which is to the mass of rinsed beans drained for 2 minutes on a 0.239 cm screen positioned at a 15 ° angle,was determined gravimetrically (Hosfield and Uebersax, 1980).

Percent washed drained weight (PWDWT) of the bean samples wascalculated as follows:
PWDWT= WDWT (g) / weight of can contents (g) x 100
*Texture*of washed processed beans was determined using a texture shear press system (Model TA-XT Plus, Stable Micro Systems, Surrey, UK) fitted with a standard multiblade shear compression cell. Force was applied until the blades passed through the 100g bean samples. The texture data output included the peak of the curve, which indicates the shear resistance peak, and the total shear resistance, which is calculated from the total area

beneath the curve. Data were stored electronically at 0.1s interval for 12s. Compression force (kg $100g^{-1}12s^{-1}$) was determined by calculating the surface area beneath the texture curve for the 12s (De Lange and Labuschagne, 2000).

The *size* of beans selected for canning purposes is an important quality parameter(van Loggerenberg, 2004). It was determined subjectively using a scale of 1 to 7 (Hosfield*et al.*, 1984), where, size 1= very small and 7= very large, while for shape 1 = very elongated and 7 = very round beans.Uniformity in size, shape and colorwas determined subjectively using a scale of 1 to 7 where, 1 = very uniform, and 7 = very varied(Uebersax and Hosfield, 1996).

Splitting of cooked beans is one of the factors that determine the intactness of cooked beans, and was determined subjectively(Uebersax and Hosfield, 1996). Extent of splitting was evaluated on scale of 1 to 7, where 1 = very broken and 7 =very intact.

The degree of clumping indicates the extent of clumping that would occur after processing, which might lead to cultivar rejection by the processor. The degree of clumping was determined subjectively using a scale of 1 to 7 (Uebersax and Hosfield, 1996). On this scale, 1 =very high degree of clumping, and 7 =very few clumps.
The canned beans undergo loss of colour and solids to the canning medium. The loss of colour and solids to canned mediumis referred to as brine clarity. It was determined subjectively on a scale of 1 to 7 (Hosfield*et al.*, 1984), where, 1 = very cloudy brine and 7 = very clear brine.

Data analysis
Analysis of variance was performed using GenStat statistical software (VSN International, 2010). Fisher's least significance difference (LSD) test was used for mean separationat $P<0.05$ level.Correlation analysis was used to determine the degree and significance of association between canning traits at 5 and 1% probability levels.

Results:
Canning quality
The canning quality values of the study lines are presented in Tables 1 to 4. The genotypes grown at each site showed significant differences (P = .05) for all canning quality traits studied apart from hydration coefficient (HC). The grain fresh weight to yield solids required per can varied from 110.9g (KAB-RB13-326-207/1B) to 114.5g (KAB-RB13-308-222/1) at Kabete (Table 1). All the genotypes had higher fresh weight to yield the required solid than the reference variety (110.3g). However, the differences were small, and varied from 0.6 to 4.2 g per can. The hydration coefficient (HC) varied from 1.7 (KAB-RB13-471-117/2) to 2.7 (KAB-RB13-408-220/5 and KAB-RB13-327-92/1). More than 80% of the lines had higher HC compared to the industry reference variety. This implied that the new lines absorbed more water and swelled better than the current industry reference variety after soaking. The two local varieties, *Dwarf 1* and *Nyeri*had HC of 2.2 and 2.4, respectively. The hydration coefficient (2.3) of the industry reference varietywas comparable to that of the two local varieties.
There were significant differences (P = .05) in brine clarity after incubation. Brine clarity scores varied from 2 to 7. The white seeded lines showed higher brine clarity (clear) compared with the purple speckled seed types. This suggested more leaching of seed coat pigments from the coloured seed types which resulted in a more cloudy brine. Moreover, most of the purple speckled lines had significantly lower brine scores (cloudy) compared with the industry reference variety. Five new lines had significantly higher brine clarity that the reference variety after incubation. Another 15 white seeded lines had the same clarity score as the reference variety.

The brine pH before incubation varied from 5.86 (KAB-RB13-312-160/5 to 6.02 (KAB-RB13-62-9/2). All the test lines grown at Kabete Field Station had higher brine pH than the reference variety (5.66), which produced more acidic brine. However, the brine pHbefore and after incubation were not significantly different. The lowest brine pH after incubation was 5.81 and the highest was 6.01 (Table 1). Generally, the brine pH before incubation was higher than after incubation.

Results showed significant genotypic differences (P = .05) for washed drained weight before and after incubation (Table 1). KAB-RB13-46-124/1 had the highest washed drained weight (300g) and percentage washed drained weight (69%) before and after incubation (Table 1). KAB-RB13-319-194/1 had the lowest

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WDWT (253 g) and PWDWT (59%) before and after incubation. Twenty-five of the 32 lines and the two checks had significantly higher WDWT than the reference variety after incubation. The WDWT of the all other lines did not differ from that of the reference variety.

There were significant differences in PWDT among the study lines. PWDT varied from 58 to 68%. There was either an increase, decrease or no change in PWDT after incubation. PWDT was higher after incubation for most test lines and check varieties. However, the PWDT was slightly lower after incubation. Three genotypes showed was no detectable change in PWDT before and after incubation.

Results showed significant genotypic (*P* = .05) differences for texture (firmness). Texture varied from 53.85 to 124.4kg 100 g^{-1} across the sites (Tables 2 and 4). At Kabete, KAB-RB13-46-124/1 (white seeded) had the lowest texture (53.85 kg 100 g^{-1}) while KAB-RB13-314-192/1 (purple speckled) had the highest texture (112.31 kg 100 g^{-1}). The reference variety, TruFood RB, had a texture of 75.02 kg 100 g^{-1}. Twenty-one new lines had texture comparable to that of the reference variety (Tables 2 and 4).

Size, shape and uniformity are important physical characteristics of grain destined for canning. Results indicated that there was considerable variation in seed size among the new runner bean lines. Size scores of the test genotypes ranged from 4 to 7. KAB-OL-RB13-440-232/2 had the highest score, while KAB-RB13-294-204/1 and KAB-RB13-343-189/5A had the lowest. KAB-OL-RB13-440-232/2, a purple speckled genotype had the largest seeds. Twenty-nine new lines had larger seeds than the industry reference variety,which had a size score of 4 (Table 2).

The cooked seeds of the study lines were either elongated, moderately elongated or oblong in shape. These are characteristic shapes of runner bean seeds. Kay (1979) described the shape of runner bean seeds as oblong. Shape score ranged from 1 to 5. Beans with a size of 1 are considered exceptionally small.The industry reference variety had a shape score of 2 indicating elongated seeds.

Results showed that the canned beans of the new lines were relatively uniform in size. Uniformity scores varied from 1 to 3.The industry reference variety also had relatively uniform seeds with a score of 2. Eleven new lines showed exceptionally high uniformity of size (Table 2). These lines had a uniformity score of 1. Another 15 lines had the same degree of uniformity as the check variety (score of 2). Only three lines had higher uniformity scores suggesting less uniformity in seed size.

Results showed considerable variation for visual appearance parameters such as splitting and clumping among the test genotypes. Splitting varied from 3 to 7. The reference check variety had a split score of 6. This implied that the study lines had a lower frequency of beans with cracks, splits and loose skins. Five lines showed outstanding integrity of beans after canning. These were KAB-RB13-312-160/5, KAB-RB13-314-192/1, KAB-RB13-341-143/A, KAB-RB13-471-117/2 and SUB-OL-RB13-269-129/3B at Kabete, and SUB-OL-RB13-275-248/3 at Ol Joro-Orok (Tables 2 and 4). These lines had a perfect score of 7. Degree of clumping of canned beans varied from 3 to 7. Beans with a score of 1 solidly clump at the bottom, while those with a score of 7 show no clumping and are easily decanted. Thirteen new lines showed no clumping and were very suitable for canning (Table 1). These lines had a score of 7 and were superior to the industry reference variety, which had a clumping score of 6.

Canning quality of lines grown at Ol JoroOrok

There were significant differences (*P*= .05) for all canning qualities apart from HC among genotypes grown at Ol Joro-orok (Tables 3 and 4). Fresh weight to yield solid required varied from 109.9g to 112.43 g. KAB-RB13-297-144/2 recorded the lowest fresh weight to yield solid while SUB-OL-RB13-326-251/4 recorded the highest. KAB-RB13-85-18A/4 had the highesthydration coefficient of 2.9 and KAB-RB13-338-41/1 had the lowestvalue of 2.1. Dwarf 3, local variety, had HC of 2.6 while TruFood RB variety had 2.3 (Table 3). KB-RB13-310-161/5 had the highest brine pH before (pH=6.00), and after incubation (6.08). SUB-OL-RB13-326-251/4 had the lowest brine pH before (pH=6.00), and after incubation (pH=5.96). The reference variety had brine pH of 5.66 before incubation, and 5.68 after incubation. The lowest WDWT and PWDWT before and after incubation were recorded in KAB-RB13-297-144/2, while the highest was recorded in KAB-RB13-338-41/1. The reference variety had a WDWT of 264 g and PWDWT of 57% before incubation, which increased to a WDWT of 269g and PWDT 58% after incubation. As in Kabete, 80% of genotypes grown at Ol JoroOrok met minimum standards for WDWT and PWDWT of 60% required by the bean processing industry (Canada Agricultural Products Standards Act, 1978). Among lines grown at Ol JoroOrok, texture varied from 57.49 kg 100 g^{-1} (KAB-RB13-338-41/1, white seeded) to 124.4 kg 100 g^{-1} (KAB-RB13-310-162/1, purple speckled). White seeded lines had lower texture than purple speckled lines across the sites. The texture of the reference variety was comparable with that of 21 new white seeded lines across the sites. All the new purple speckled lines across the sites had higher texture than the reference variety (75.02 kg 100 g^{-1}) (Tables 2 and 4).

The physical characteristics of genotypes grown at Ol Joro-Orok were comparable to those recorded for genotypes grown at Kabete Field Station. All the genotypes had size score of five and above. KAB-RB13-297-144/2, KAB-RB13-310-161/5 and KAB-RB13-471-117/1 had the largest seeds (score of 7). All the other genotypes had size score of 5 indicating medium size seeds. KAB-RB13-310-161/5 had seed size score of 7 (very large), shape of 1 (very round), and uniformity of 1 (very uniform).

Results showed considerable variation for visual appearance parameters at Ol Joro-Orok (Table 4). SUB-OL-RB13-275-248/3 had the highest score of splits and clumps (7), implying that the canned product of this line remained very intact and with very few clumps. However, it had moderately cloudy brine (score of 2) indicating the grain lost colour to media during the canning process. The visual appearance score for the industry check variety at Ol Joro-Orok was 6 for splits, clumping and brine clarity (Table 4). However, the best performing lines at the two sites differed suggesting a strong genotype x environment interaction for canning traits.

Correlation analysis

There were significant correlations (P = .05 and .01) between some attributes of the advanced grain runner bean lines (Table 5). Brine clarity was negatively and significantly correlated with clumping (r= -0.34*), degree of splitting (r= -0.43**), seed size (r= -0.35*) and texture (r= -0.88**). This meant that beans with clear brine had fewer clumps and a low degree of splitting. Clear brine was associated with small seed size and soft texture. In addition, brine clarity was positively correlated to PWDWT (r= 0.52**) and WDWT (r= 0.56**). This suggests that beans with clear brine imbibed more water during canninghence lower proportion of solids (Table 5). However, there was no correlation between HC and fresh weight to solid yield required with other canning traits. This may imply that water imbibition during soaking and blanching may not be influenced by other traits. WDWT and PWDWT had a strong positive correlation (r= 0.95**) suggesting that the higher the WDWT the higher the PWDWT. PWDWT was negatively correlated to texture (r= -0.61**) and degree of splitting (r= -0.48**). This implied that when beans imbibe more water during canning they are likely to become softer and very broken (Table 5). Seed size was positively correlated to texture (r= 0.35*) and splitting (r= 0.42**). Large seeded beans tend to be firmer and very intactprobably because they imbibe less water as opposed to small seeded beans. Texture was positively correlated to splitting (r= 0.48**) but negatively correlated to WDWT (r= -0.64**). This suggested that beans with high texture were likely to be remain intact and imbibe less water during canning. Degree of splitting was negatively correlated with WDWT (r= -0.51**) and PWDWT (r= -0.48**). This implied that beans with a high proportion of washed drained weight tended to have low levels of splitting (very intact) (Table 5).Brine pH had no correlation with other canning traits. It is probably influenced by other factors such as environment and genetic makeup.

Discussion:

One of the current objectives of bean breeding programs in eastern Africa is to develop improved varieties which are not only agronomically superior in farmers' fields, but also have acceptable canning quality desired by the processing industry. New agronomically superior dry bean lines that meet industry criteria were recently developed and released in Kenya (Warsame and Kimani, 2014). However, the development of runner bean varieties suitable for canning has received little research attention in eastern Africa. This may have contributed to the limited availability of literature on canning aspects of runner bean. The present study is an attempt to provide such information and to identify new lines that meet requirements of the canning industry.

Hosfield and Uebersax (1996) developed physical and chemical composition tests for dry bean that provide a basis for differentiating and selecting breeding lines for canning quality. These canning quality traits relate to those that have economic impact for the processing industry, and those that affect appeal and palatability of the canned product (Khanal et al, 2015). Results of this study revealed considerable variation for important canning quality traits among the new runner bean lines.Fresh weight to yield required is an important factor to processors because it determines the quantity of seed solids required to be soaked and blanched to fill a can. On the basis of the laboratory canning protocol developed by Michigan State University (MSU), a fresh-mass equivalent of 100 to 115 g solids is required for 15 oz (303 x 406mm) cans for soaking and blanching in water containing 50 to 100 mg Ca kg^{-1}(Hosfield and Uebersax, 1980; Uebersax and Bedford, 1980). The fresh weight solids for elite lines used in this study varied between 110 and 114 g and were therefore within the optimum range.

Among canning quality traits, hydration coefficient (HC) is considered a very vital trait in bean canning industry as it indicates the amount of seeds needed to fill the can after soaking and blanching (Loggerenberg, 2004). An HC of 1.8 to 2.0 is considered optimum by the industry and gives an indication of well-soaked beans (Balasubramanian*et al.*, 2000). Hosfield and Uebersax (1980) found the HC of seven types of white dry beans to range from 1.82 to 1.94. In a study of three navy bean cultivars, Balasubramanian*et al.*, (1999) found the same order of HC ranges (1.84 to 1.96). The significance of HC to processors is that a larger quantity of beans is necessary to fill a certain can volume if the HC ratio is low. A higher HC would therefore improve canning yield (Ghaderi*et al*., 1984). The hydration coefficient of the elite lines used in this study varied from 1.7 to 2.9. The higher HC values are probably due to genetic factors and the larger seed size of runner beans. The industry reference variety used in this study had a HC of 2.3, suggesting a broader range of acceptable values for runner bean.

The Canadian Agriculture Products Standards Act (1978) requires that PWDWT of canned beans should not be less than 60%. Loggerenberg (2004) stated that a WDWT of 272 is the industry standard used in South Africa.Sixteen elite lines met the above standards for both WDWT and PWDWT. However, only eight lines across the sites failed to meet the standard for PWDWT. According to Loggerenberg (2004), the PWDWT after incubation for 7 days was higher than PWDWT before incubation for 24 hours. In the present study, differences in PWDWT between cultivars were more pronounced after incubation. This could be due to further water uptake inside the can during the first seven days after canning (Bolles et al., 1982). Seventeen lines had higher PWDWT after incubationconsistent with the above reports, while the rest did not. PWDWT of 60% was comparable with results reported by other researchers. Loggerenberg (2004) found both laboratory and industrial canning of Teebus variety were close to the 60% standard set by Canadian government regulations (Balasubramanian*et al.*, 1999). Kabete line KAB-RB13-471-117/2 with the lowest HC (1.7) achieved PWDWT comparable with SUB-OL-RB13-269-129/3B which had HC of 2.5. This suggests that beans undergo more weight increase due to equilibration of beans and brine in the can. Loggerenberg (2004) suggested that WDWT is a function of the equilibrium of beans and brine in the can, and is highly dependent on the moisture content of the beans after soaking, the fill weight and the brine fill. Lack of significant differences in HC among the genotypes could be due to the fact that the genotypes had small differences in seed size hence imbibed less water.Warsame (2013) found significant differences in HC between the large and small seeded genotypes across seven market classes of beans. He attributed the differences to factors inherent in seeds. The small, white seeded genotypes had higher water uptake (WU) and HC than the large purple speckled genotypes. Del Valle *et al.,* (1992) reported that seed coats of white beans are preferentially permeable to water when compared with those of black and red beans.Results of this showed that the white seeded beans had higher HC than the coloured seeds, which were in agreement with those reported by Del Valle *et al.,* (1992). Our results confirmed absence of significant correlation between HC and other traits. However, Khanal*et al.,* (2015) reported negative correlation between HC and PWDWT (r= -0.62 P>0.001).Absence of correlation between HC and seed size could be probably due to use of elite lines which had small differences in seed size and therefore imbibedcomparable amounts of water.

Texture is used as an indication of relative hardness or softness of canned bean(Ghaderi*et al*., 1984; Hosfield, 1991). It is relatedto degree of consumer acceptance of the product as it affects the perceived stimulus of chewing (Ghaderi*et al*., 1984). Consumers usually rate texture of beans from “too soft” or “mushy” to “too firm / tough” or “hard” (Hosfield, 1991). There was significant variation for texture between the two seed types. The white seeded varieties from both sites had softer texture than coloured seed varieties. The texture varied from 53.85 to 85.05 kg $100g^{-1}$for the white seeded, and 97.44 to 124.4 kg $100g^{-1}$ for the coloured seedsacross the sites. This indicates that seed colour may have some influence on texture. In our study, there was high negative correlation between texture and brine clarity (r= -0.88**), which was probably a reflectionof seeds colour. Loggerenberg (2004)also reported a negative correlation between texture and a_L-value colour of seeds (red to green) in four small white bean cultivars. Texture, which is measured by a shear press, is an indication of the firmness of the beans (Ghaderi *et al*., 1984) and is measured as kg force required to shear 100 g of beans (Hosfield and Uebersax, 1980). The shear press curve is used to indicate maximum shear force by means of maximum peak height. A higher maximum peak height indicates firmer beans (Bolles et al., 1990).In our study 20 lines had soft to medium texture while all the coloured lines had hard texture. In this research, texture correlated negatively with PWDWT (r= -0.61**). Loggerenberg (2004) also found that texture was negatively correlated with PWDWT in small white bean cultivars (r= -0.57**). Negative correlation between texture and PWDWT, also was previously reported by Ghaderi*et al.*,(1984), Balasubramanian*et al*., (1999)and Khanal*et al.* (2015). Khanal*et al.* (2015) found a highly significant negative correlation between texture and PWDWT r= -0.37 (P>0.01). This indicated that hard seeds imbibe less water during canning compared to softer seeds. Consumers always prefer seeds with soft to medium texture.The correlation between HC and texture among the new runner bean lines was not significant. He *et al*, (1989) and Loggerenberg, (2004) also found that the correlation between HC and texture was not significant. Texture of the new runner bean lines varied from53.85 to 124.4 kg $100g^{-1}$across the sites. Our results are consistent with findings of Loggerenberg (2004) who reported that texture for the reference standard for choice grade (Teebus)was 70.21 kg $100g^{-1}$,and 75.26 kg $100g^{-1}$for standard grade (Helderberg) beans. The mean texture value agreed with the USA guidelines of 72 kg $100g^{-1}$ in bean cultivars. This indicates that runner beans are comparable with common beans texture since they belong to the same family.

Size and shape of canned beans are important for the canning industry due to consumer preferences. Beans destined for canning purposes should be uniform in size with regular shape. Uniformity is a key factor considered by the processing industries. Lines used in this study showed a high degree of uniformity, which was probably reflected single pod selection approach used followed during the breeding process.

Visual appearance of canned beans is a useful indicator of the general suitability of beans for commercial processing (Hosfield and Uebersax, 1980). Canned beans are evaluated for splits, free seed coats, clumping, and brine clarity (Hosfield and Uebersax, 1980). Lines used in this study showed acceptable scores for splits, low degree of clumping and high brine clarity of the canned products compared with the industry reference variety indicating that they met critical visual appearance parameters, and hence their suitability for commercial processing.

Several workers have reported that bean genotypes that have high PWDWT tend to split (Loggerenberg, 2004; Balasubramanian*et al*., 2000; Mekonnen, 2012). Results for this study confirmed these findings. There wassignificant negative correlation (r= -0.48**, P<0.01) between splits and PWDWT, and also betweensplits and WDWT (r= -0.51**, P<0.01). Buren et al., (1986) also reported that the incidence of splits after canning is lower in beans with low PWDWT values. Warsame and Kimani (2014) reported that frequency of splits varied with bean market classes and seed size. The lowest scores for splits was recorded among the small seeded navy and large-seeded red kidney bean market classes. The navy beans had the highest PWDWT among the small seeded beans. Red kidney beans had the second highest PWDWT among the large seeded types. Faris and Smith (1964) suggested that large sized beans have fewer splits, due to smaller volume-to-surface ratio. Loggerenberg (2004) found larger seeds had fewer splits. Result of the present study showed a significant positive correlation (P>0.01) between seed size and splits.

TruFood RB is the canning industry reference variety. However, canning quality attributes expected from the variety but it did not reveal that superiority. However, 36 elite lines were better than the TruFood check variety in canning quality. They had better fresh weight to yield solid, HC, PWDWT and WDWT compared to the TruFood check variety which indicated that less seeds are required for soaking and blanching, less seed required to fill the cans after soaking and blanching and more water is imbibed during. This is an indication that these lines can be used to produce even better products. Canning quality parameters in this study were based on canning in brine. It may be useful to evaluate these lines using tomato sauce as canning media to meet a broader range of consumer preferences for the end product.

Conclusions:

The 43 grain type runner bean genotypes evaluated in this study showed significant differences for canning qualities which are probably due to genetic factors inherent in the genotypes. Results showed that lines SUB-OL-RB13-269-129/3B, KAB-RB13-341-143/A, KAB-OL-RB13-440-232/2 at Kabete, and KAB-RB13-310-161/5 and KAB-RB13-471-117/1 at Ol-Joro-Orok, had superior canning quality attributes compared to existing canning grain runner bean variety, TruFood RB variety. These lines were also superior for agronomic traits compared to local varieties. They represent the first generation of locally bred runner bean lines that fully meet canning criteria of the processing industry. Utilization of these lines can contribute to better productivity of runner bean, and improved supply of raw materialsfor the processing industryin Kenya and probably eastern Africa region. The results and germplasm developed in this project provide a baseline for further improvement of grain type runner bean in this region.

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Table 1. Canning quality characteristics of grain runner bean lines grown at Kabete Field Station during the 2014 long rain season.

Genotype	Seed colour	Fresh weight to yield solid (g)	Hydration coefficient (HC)	Brine pH		Brine clarity		WDWT (g)		PWDWT (%)	
				AI	BI	AI	BI	AI	BI	AI	BI
KAB-OL-RB13-440-232/2	Purple speckled	111.4	2.1	5.91	5.93	3	2	259	259	59	61
KAB-RB13-294-204/1	White	112.2	2.4	5.96	6.00	7	6	270	268	61	63
KAB-RB13-303-146/1	White	111.9	2.5	5.85	5.83	7	6	268	265	62	61
KAB-RB13-308-222/1	White	114.5	2.4	6.01	6.01	7	6	278	286	64	66
KAB-RB13-310-161/2	Purple speckled	111.0	2.2	5.90	5.89	2	2	260	258	61	60
KAB-RB13-312-160/5	Purple speckled	112.3	2.1	5.81	5.86	2	2	258	262	59	60
KAB-RB13-314-192/1	Purple speckled	111.1	2.5	5.84	5.89	2	2	261	264	61	60
KAB-RB13-319-182/1	White	113.5	2.5	5.92	5.92	6	5	270	270	63	62
KAB-RB13-319-182/4	White	111.8	2.2	5.94	5.95	6	5	269	272	62	64
KAB-RB13-319-194/1	Purple speckled	113.2	2.5	5.85	5.88	3	2	257	253	59	59
KAB-RB13-321-185/1	Purple speckled	113.3	2.3	5.89	5.90	2	2	261	260	59	60
KAB-RB13-326-207/1B	Purple speckled	110.9	2.4	5.93	5.94	2	2	260	262	60	61
KAB-RB13-327-48/1	White	114.3	2.4	5.94	6.01	6	5	283	277	66	63
KAB-RB13-327-92/1	White	111.2	2.7	5.93	5.93	5	6	264	270	61	63
KAB-RB13-329-164/2	White	112.3	2.3	5.91	5.88	6	6	272	270	63	62
KAB-RB13-329-165/1	White	113.1	2.3	5.95	5.99	6	5	272	274	64	64
KAB-RB13-329-165/3	White	112.3	2.5	5.92	5.90	5	6	268	266	64	61
KAB-RB13-341-143/A	Purple speckled	111.6	2.0	5.93	5.93	2	2	267	264	63	61
KAB-RB13-343-189/5A	White	112.6	2.4	5.93	5.87	7	6	265	266	62	61

KAB-RB13-379-147/3	White	112.4	2.4	5.94	5.88	6	5	268	271	61	64
KAB-RB13-399-219/4B	White	113.1	2.6	5.82	5.87	6	6	274	272	62	62
KAB-RB13-403-150/2	White	111.2	2.5	5.95	5.94	7	6	272	270	63	62
KAB-RB13-403-150/4B	White	113.1	2.4	6.00	5.99	6	5	282	286	65	66
KAB-RB13-408-220/5	Purple speckled	111.2	2.7	5.87	5.92	2	2	259	258	58	59
KAB-RB13-46-124/1	White	113	2.4	5.95	6.01	6	5	298	300	68	69
KAB-RB13-46-124/3A	White	111.2	2.3	5.98	6.01	6	5	278	280	65	63
KAB-RB13-471-117/2	White	111.1	1.7	5.94	5.98	6	6	262	270	60	63
KAB-RB13-471-117/3	White	111.7	2.3	5.99	5.98	6	6	275	274	64	63
KAB-RB13-62-9/2	White	112.3	2.3	5.96	6.02	6	6	284	274	65	63
SUB-OL-RB13-177-3/5	White	111.6	2.4	5.91	5.93	6	6	272	270	62	62
SUB-OL-RB13-178-239/4	White	112	2.4	5.94	5.96	6	6	271	270	64	62
SUB-OL-RB13-269-129/3B	Purple speckled	112.4	2.5	5.93	5.92	2	2	255	260	60	61
Checks											
Dwarf 1	Purple speckled	112.3	2.2	5.97	5.98	2	2	261	256	60	58
Nyeri	Purple speckled	112.7	2.4	5.96	6	2	2	263	262	62	61
TruFood reference variety	White	110.3	2.3	5.68	5.66	6	5	259	264	58	57
Mean		111.8	2.4	5.93	5.96	5	4	269	269	6.2	62
LSD (0.05)		0.09*	0.5ns	0.04*	0.47*	0.7*	1*	5.5*	9.9*	2*	3*
CV%		0.4	9.5	0.3	0.4	7.4	7	1	1.8	1.6	2.4

LSD=least significant difference, CV=coefficient of variation, AI=after incubation, BI=before incubation, WDWT=washed drained weight, PWDWT-percent washed drained weight
*, ** Significant at 0.05, 0.01 probability levels; ns=not significant.

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Table 2. Texture, seed size, shape, uniformity, split and clumping scores of grain runner bean lines grown at Kabete Field Station during the 2014 long rain season and canned in brine.

Genotype	Texture (kg 100g^{-1})	Seed size	Shape	Uniformity	Splits	Clumping
KAB-OL-RB13-440-232/2	108.43	7	2	2	6	7
KAB-RB13-294-204/1	67.18	4	2	3	6	6
KAB-RB13-303-146/1	73.0	5	3	3	5	6
KAB-RB13-308-222/1	60.4	5	3	1	5	6
KAB-RB13-310-161/2	112.17	6	2	2	6	6
KAB-RB13-312-160/5	111.49	6	2	1	7	7
KAB-RB13-314-192/1	112.31	5	2	2	7	7
KAB-RB13-319-182/1	62.77	5	3	2	6	6
KAB-RB13-319-182/4	76.58	6	2	1	6	6
KAB-RB13-319-194/1	107.59	6	2	2	6	6
KAB-RB13-321-185/1	109.49	6	2	2	6	7
KAB-RB13-326-207/1B	103.46	5	3	1	6	7
KAB-RB13-327-48/1	60.93	6	2	3	6	6
KAB-RB13-327-92/1	73.89	5	3	3	6	6
KAB-RB13-329-164/2	62.8	6	2	2	6	7
KAB-RB13-329-165/1	80.66	6	2	3	6	7
KAB-RB13-329-165/3	85.05	6	3	2	6	6
KAB-RB13-341-143/A	107.05	6	2	1	7	7
KAB-RB13-343-189/5A	66.67	4	4	3	6	6
KAB-RB13-379-147/3	64.83	5	3	1	6	7
KAB-RB13-399-219/4B	60.53	5	2	1	6	7

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KAB-RB13-403-150/2	65.3	6	3	1	6	6
KAB-RB13-403-150/4B	61.17	6	2	2	5	6
KAB-RB13-408-220/5	97.44	6	2	1	6	7
KAB-RB13-46-124/1	53.85	3	1	2	3	6
KAB-RB13-46-124/3A	60.38	6	2	2	6	6
KAB-RB13-471-117/2	60.93	6	2	1	7	7
KAB-RB13-471-117/3	61.72	6	2	2	6	6
KAB-RB13-62-9/2	58.57	6	2	2	5	6
SUB-OL-RB13-177-3/5	59.58	5	2	2	6	6
SUB-OL-RB13-178-239/4	63.02	5	3	2	6	6
SUB-OL-RB13-269-129/3B	114.66	6	2	1	7	7
Checks						
Dwarf 1	100.19	6	2	2	6	5
Nyeri	101.89	5	3	3	4	6
TruFood reference variety	75.02	4	2	2	6	6
Mean	81.77	6	2	2	6	6
LSD (0.05)	144.6*	0.7*	0.5*	0.5*	0.8*	0.5*
CV%	8.8	6	10.1	12.7	6.9	3.9

LSD=least significant difference; CV=coefficient of variation; *, ** Significant at 0.05, 0.01 probability levels, respectively.

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Table 3. Canning quality characteristics of grain runner bean lines grown at Ol-Joro-Orok in 2014.

Genotype	Seed colour	Fresh weight to yield solid (g)	Hydration coefficient (HC)	Brine pH		Brine clarity		WDWT (g)		PWDWT (%)	
				AI	BI	AI	BI	AI	BI	AI	BI
KAB-RB13-297-144/2	Black	109.9	2.5	6.01	5.97	2	2	256	256	59	59
KAB-RB13-310-161/5	Purple speckled	110.7	2.3	6.08	6	3	2	258	254	59	58
KAB-RB13-310-162/1	Purple speckled	109.7	2.2	5.93	6.08	2	2	261	264	60	62
KAB-RB13-326-207/1	Purple speckled	110.9	2.2	6.01	6.05	3	2	256	260	60	61
KAB-RB13-338-41/1	White	110.7	2.1	5.98	6.06	6	6	312	304	73	70
KAB-RB13-379-148/1	Purple speckled	110.2	2.4	5.97	6	3	2	259	260	59	61
KAB-RB13-471-117/1	White	110.3	2.6	5.99	6.05	5	6	274	276	64	65
KAB-RB13-85-18A/4	White	110.7	2.9	5.93	6.04	6	5	306	300	71	68
SUB-OL-RB13-226-251/4	White	110.1	2.2	5.98	6.05	6	6	288	284	66	66
SUB-OL-RB13-275-248/3	Purple speckled	112.3	2.5	5.99	6.05	2	2	262	258	60	60
SUB-OL-RB13-326-251/4	White	112.4	2.6	5.96	6	6	5	262	268	62	63
Checks											
Dwarf 3	White	111.3	2.6	5.93	5.99	7	6	268	270	63	62
TruFood RB variety	White	110.3	2.3	5.68	5.66	6	5	259	264	58	57
Mean		111.8	2.4	5.93	5.96	5	4	269	269	6.2	62
LSD (0.05)		0.09*	0.5ns	0.04*	4.7*	0.7*	1*	5.5*	9.9*	2*	3*
CV%		0.4	9.5	0.3	0.4	7.4	7	1	1.8	1.6	2.4

LSD-least significant difference, CV-coefficient variation, AI-after incubation, BI-before incubation, WDWT-washed drained weight, PWDWT-percent washed drained weight. *, ** Significant at 0.05, 0.01 probability levels respectively,ns=not significant

Table 4. Texture, seed size, shape, uniformity, splits and clumping scores of grain runner bean lines grown at Ol-Joro-Orok during long rain 2014 and canned in brine.

Genotype	Texture ($kg100g^{-1}$)	Seed size	Shape	Uniformity	Splits	Clumping
KAB-RB13-297-144/2	101.92	7	1	3	6	7
KAB-RB13-310-161/5	113.46	7	1	1	6	7
KAB-RB13-310-162/1	124.4	6	2	3	6	7
KAB-RB13-326-207/1	97.85	5	2	3	6	7
KAB-RB13-338-41/1	57.49	6	2	2	5	3
KAB-RB13-379-148/1	101.55	6	2	3	6	7
KAB-RB13-471-117/1	55.79	7	1	1	6	7
KAB-RB13-85-18A/4	66.62	5	3	2	5	6
SUB-OL-RB13-226-251/4	54.81	5	5	2	6	7
SUB-OL-RB13-275-248/3	120.31	6	2	2	7	7
SUB-OL-RB13-326-251/4	67.7	5	2	2	6	7
Checks						
Dwarf 3	73.51	6	2	2	4	6
TruFood RB variety	75.02	4	2	2	6	6
Mean	81.77	6	2	2	6	6
LSD	144.6*	0.7*	0.5*	0.5*	0.8*	0.5*
CV%	8.8	6	10.1	12.7	6.9	3.9

LSD-least significant difference, CV-coefficient variation. *, ** and ns Significance at 0.05, 0.01 probability level and not significant

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Table 5. Correlation matrix between canning quality parameters of runner bean lines

	Brine pH	Brine clarity	Clumping	Fresh weight to yield required (g)	Hydration coefficient (HC)	PWDWT	Seed size	Shape	Texture (kg 100g^{-1})	Splits	Uniformity	WDWT (g)
Brine pH	1											
Brine clarity	0.05	1										
Clumping	-0.11	-0.34*	1									
Fresh weight to yield required (g)	-0.02	0.24	-0.10	1								
Hydration coefficient (HC)	-0.06	0.10	-0.01	0.08	1							
PWDWT	0.27	0.52**	-0.57**	0.09	0.08	1						
Seed size	0.18	-0.35*	0.13	-0.22	-0.18	-0.23	1					
Shape	-0.09	0.34*	-0.10	0.06	0.09	0.15	-0.24	1				
Texture (kg 100g^{-1})	-0.04	-0.88**	0.39**	-0.25	-0.13	-0.61**	0.35*	-0.24	1			
Splits	-0.19	-0.43**	0.52**	-0.10	-0.20	-0.48**	0.42**	-0.05	0.48**	1		
Uniformity	0.11	0.02	-0.14	0.01	0.12	0.04	-0.16	0.11	0.07	-0.20	1	
WDWT (g)	0.21	0.56**	-0.55**	0.09	0.08	0.95**	-0.29*	0.14	-0.64**	-0.51**	0.00	1

Correlation coefficient significant at * p<0.05 and ** p<0.01 probability levels, PWDWT= Percent washed drained weight, and WDWT= Washed drained wei

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Authors & Affiliation

***SerahNyawiraNjau and PaulMacharia Kimani**

Department of Plant Science and Crop Protection

University of Nairobi, College of Agriculture and Veterinary Sciences

P.O Box 29053-00625 Nairobi, Kenya