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SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 22 No. 8
October 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2022; 22(8): 21269-21307 https://doi.org/10.18697/ajfand.113.21630

CANNING QUALITY OF POPULAR COMMON BEAN GERMPLASM IN EASTERN AND CENTRAL AFRICA

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October 2022
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ABSTRACT

Common bean (*Phaseolus vulgaris* L.) genotypes popular in eastern and central Africa were evaluated to determine their suitability for the canning industry. The genotypes were planted at the National Agricultural Research Laboratories (NARL), Kawanda-Uganda in the second rainy seasons (July-September) of 2015, 2016 and off season of 2017 (November- February). Two samples per genotype were evaluated at the canning facilities at Kawanda and Michigan State University (MSU) using a protocol based on home canning. One sample per genotype from the 2017 harvest was evaluated at Agriculture and Agri-Food Canada, Lethbridge Research and Development Centre (AAFC-LRDC) using the industry canning protocol. Data (n=134) was collected on seed moisture content, dry and soaked bean weight, hydration coefficient (HC) and visual quality, including colour retention, appearance, brine clarity, bean splitting and freedom starch/clumps on replicated samples. Additional data on unreplicated samples were collected on 100-seed weight, seed solids for canning, hydration coefficient after soaking (HCS), hydration coefficient after blanching (HCB), drain weight (%), matting, appearance, seed color, texture, and cooking quality traits including hard seed and partially hydrated seed (%) and HC after cooking. Analysis of variance of data from MSU and Kawanda showed significant ($P \leq 0.01$) differences among genotypes for the assessed parameters. Majority of the genotypes expressed good soaking ability considering that their HC were above the 1.8 recommended for canning and 28% combined the two mentioned traits with good overall canning quality visual rating. Apart from 26, all other varieties had good HC based on data from Canada. About 24% of genotypes belonging to various market classes consistently combined this trait with good visual quality. The most outstanding genotypes based on these traits included SAB659 (red mottled), MAC44 (red mottled), NABE21 (cream), NABE12C (cream) and VAX5 (cream), KK8 (red mottled), Bihogo (yellow) and VAX4 (black). These genotypes were superior to the white beans: MEXICO 142, Awash1, and Awash Melka, that were considered as high-quality controls. Results indicated that genotypes of diverse backgrounds, with good canning quality traits exist among the currently utilised varieties and breeding lines. This diversity could be exploited for breeding and varietal promotion in the canning industry.

Key words: Common bean, canning, hydration coefficient, visual quality, drained weight

INTRODUCTION

Common bean is the most important directly consumed food legume in the world, and it is an important source of dietary protein in Africa where it feeds over 400 million people [1]. The crop is also an important source of energy, fiber and micronutrients especially iron, zinc, thiamin and folic acid [2, 3]. Local consumers within the East African region majorly buy beans in a dry unprocessed form, which is 55% cheaper than the least expensive processed bean product [4]. However, the cost is only 15% cheaper if the cost of water and fuel used to prepare and cook dry beans are considered [4]. There is an increasing number of middle-income consumers in East Africa, who are majorly city dwellers and are willing to pay for the convenience of pre-cooked/canned beans. Canned beans are not only convenient in terms of time and fuel but are also safe, and have potential to be combined with other foods thereby creating new product lines especially for improved nutrition. This market segment is expected to expand considering the ever-growing urban populations and the current change in lifestyle [4].

To be more relevant to the market, it is important for breeding programs to consider important canning quality traits. These include both processor and consumer preferred traits like short cooking time, high canning yield, bean texture and splitting after cooking, grain size and uniformity [5, 6]. Good canning quality is imperative since a variety with poor culinary quality will be rejected by consumers and processors regardless of how agronomically superior it is [7]. It is for this reason that the popular bean germplasm in east and central Africa were evaluated for canning quality to assess the availability of beans possessing these traits among the preferred varieties and to better inform the breeding programs. Some varieties were identified and are being utilized in the canning industry in Ethiopia [8] and Democratic Republic of Congo [9]. In 2014, Warsame and Kimani [10] carried out a similar study, the first of its kind in over 50 years in Kenya and discovered three new small-seeded white beans superior in canning quality traits than the long-preferred variety, MEXICO 142. However, the identified genotypes do not capture the diversity in the market classes especially in grain color and size [10]. Also, the resilience of these genotypes to the prevailing biotic and abiotic stresses is important for canning industry sustainability.

The canning quality of common beans is influenced by the genotype, environment and genotype by environment interactions, in addition to the seed handling and processing methods after harvest [5, 11, 12, 13, 14, 15]. For most of these studies, variation due to genotype seems consistently higher than that of environment or genotype by environment interactions for most of the important quality traits. In a study of black bean populations, it was reported that selection for superiority in canning traits is unlikely to cause yield drag [16]. This is very important because yield is a key trait to both farmers and processors. To advance research and commercialization of canned bean, several protocols including Michigan State University (MSU) laboratory protocol based on home canning, industry method and near-infrared spectroscopy [12, 17] have been developed. Canning quality traits in dry beans are affected by the calcium level in the soak water, blanch water and brine, as well as the soaking and blanching time used during evaluation [18]. The MSU home canning-based protocol, that adjusts for these variations, and industry-based protocol used at Agriculture and Agri-Food Canada, Lethbridge Research and Development Centre, Canada (AAFC-LRDC) were used to determine the canning quality of popular climbing and bush beans in east and central Africa as a background study to initiate selection and breeding for these traits.

MATERIALS AND METHODS

Bean germplasm evaluated

One hundred and thirty-four (134) genotypes, consisting of land races (6%), varieties released in some of the member countries (Burundi, Ethiopia, Kenya, Malawi, Rwanda, Uganda, and Tanzania) of the Pan Africa Bean Research Alliance; PABRA (https://www.pabra-africa.org) (66%), and breeding lines (28%) commonly used for varietal improvement were evaluated for canning traits (Table 1). Most (88%) of the evaluated materials were of bush growth habit and of medium (45%) and small seed size (40%). Red mottled, reds, speckled and whites were the most common seed colors in the evaluated panel (Table 1).

Field trial set up

Experiments were set at the Alliance for Bioversity and International Centre for Tropical Agriculture (CIAT) station in Uganda that is based at the National Agricultural Research Laboratories (NARL), Kawanda. The NARL is in Nabweru sub-county, Wakiso District about 13Km from Kampala city. It is located longitude 45˚N and latitude 48˚E and is 1190 m above sea level with an average temperature of 22°C and 1242 mm annual rainfall.

Three trials that included i) second rain season (July-September) of 2015, ii) second rainy season (July-September) of 2016 and iii) off season (November 2017-February 2018) were used in this study. The trials were planted in randomized complete block design (RCBD) with two replications. Plot size was 3 x 3 m. At harvest, seeds were sun dried to recommended moisture content (10-15%)

and hand sorted to remove foreign matters, physically damaged beans and undesirable types.

For canning assessments, the seeds harvested from the 2015 trial were sub divided into three: one set of 250 g of seeds per germplasm were shipped to USDA-ARS; Sugarbeet and Bean Research Unit, East Lansing, Michigan, another set was assessed at CIAT-Kawanda, and the third set was field evaluated at Kawanda during the July-September rain season of 2016. The harvested seeds were subdivided into two: one set was tested for canning quality at CIAT-Kawanda and the other set including an additional 14 lines to make it 134 lines were replanted in the 2017 off season (November 2017-Februray 2018) and the harvested seed (500 g) sent to LRDC-Canada in April, 2018 and tested for canning and cooking quality. In summary, four sets of canning data: one from the Sugarbeet and Bean Research Unit at MSU (2015), two from Kawanda-Uganda (2015 and 2016) and one from Canada (2017) were generated.

Canning quality assessments at Michigan State University and CIAT-Uganda
The MSU bean canning laboratory protocol was based on a home canning method developed by Uebersax and Hosfield [19] and later designed to fit the United States and Canada canning industry standards [17]. The procedures involved cold and hot soaking of bean samples, brine preparation, autoclaving, storage and evaluation for consumer traits. Harvested seeds were sorted to remove any foreign matters, physically damaged beans and undesirable types. Sub-sampling was done for each sample to obtain 2 or 3 samples per experimental unit and samples labelled uniquely. For the first two analysis, only one sample per genotype was canned in each of the laboratories due to limited seed quantities, and thus laboratories were considered as duplicates. The moisture content of each sample was recorded using a DICKEY-John GAC 2500GMA and a SINAR Model 6095 AgriPro Moisture Analyzer at Michigan and Kawanda, respectively. For each sample an equivalent of 90 g of solid was collected. This is the fresh weight of beans equivalent to 90 g of total solids at a given moisture content that is estimated using the moisture content (%MC) of each sample, for example, 107.1 g of bean fresh weight at 16% MC is equivalent to 90 g solids, that is,

$$\text{Dry bean weight (weight for canning) in grams} = \frac{90\text{ g (solids required)}}{1-\left(\frac{\text{MC\%}}{100}\right)\text{ (solids at a given moisture content)}}$$

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The dry beans were processed using a standard soak procedure. Seed samples were placed in heat resistant nylon mesh bags and designated into soak lots. Two soaks were performed: cold and hot soak. The soak solution comprised of 0.28 g of calcium chloride ($CaCl_{2)}$ dissolved in 1 liter of distilled H_2O. Calcium ion influences the quality of processed beans and thus the MSU protocol recommends using 75-100 ppm of calcium ions. For cold soaking, $CaCl_2$ solution was prepared by weighing 2.8 g of $CaCl_2$ and dissolving it in 10 liters of distilled water in a plastic bucket. The mixture was stirred to obtain a clear solution before bean samples packed in heat resistant nylon mesh bags were immersed. White beans were soaked separately from colored or black beans. Seed color and type is known to influence cold soaking duration [17]. Therefore, navy (white), great northern, pink and small red beans were soaked for 30 min while red kidney, red mottled, cranberry, and pinto beans were soaked overnight (12-14 hrs) in large plastic buckets and at room temperature (25°C). Thereafter, hot soaking was done by transferring samples from cold storage into preheated $CaCl_2$ solution; prepared similarly to the one for the cold soak, into a boiler. The bean samples were submerged in the solution for 30 min for all market classes. Thereafter, the samples in mesh bags were removed from the boiler and placed in a large container of cold tap water for 3-5 min and afterwards removed and spread out on flat perforated surface to facilitate uniform drainage for 10-15 min. The soaked seeds were then transferred into labelled, uniformly sized, heat resistant glass jars whose weights were determined by randomly weighing 5 empty jars and obtaining an average. The filled jars were then weighed and the glass jars were filled with hot brine that was prepared by mixing 2.8 g of $CaCl_2$, 150 g of sucrose (sugar) and 10 liters of distilled water in a plastic bucket (that is for 1 liter of H_2O use 0.28 g of $CaCl_2$ and 15 g of sugar). The mixture was stirred and then boiled in a steel saucepan on a gas cooker until a temperature of 87°C was attained after which the brine was transferred into glass jars (fully filled leaving 2.5 cm headspace) containing beans using a measuring cup. To prevent glass jars from breaking, they were placed in hot water during the brine filling process. The jars were then sealed and autoclaved at 120°C for 30 min (F_0 = 23.3 min) after which they were removed and transferred into cardboard boxes and stored at room (ambient) temperatures for a minimum of two weeks at MSU and four weeks at CIAT-Kawanda. The four weeks considered at Kawanda initially intended to capture the shelf life on the Ugandan market.

Canning quality assessment at LRDC-Canada

Dry bean seed samples were processed at AAFC-LRDC using industry protocols. Seeds were stored in closed containers for about 1 week to equilibrate the samples for moisture. Three high quality canning checks were included: AAC

Cranford (cranberry), AAC Expedition (pinto) and AC Black Diamond (shiny black). The percent moisture content (%MC) of the bean samples was determined using a Dickey-john 2500-UGMA Grain Analyzer.

Based on the %MC, 90 g of dry bean seeds were weighed into a 1.2 L stainless steel beaker and soaked in 1 L deionized water at ambient temperature (21°C) for 16 hours, drained, weighed, then hydration coefficient was calculated. The beans were then blanched by placing the beakers onto a closable steam table and adding about 1 L of boiling water that was maintained at 93°C using a digital thermometer equipped with a thermocouple for 3 min. Cooling to about 50°C for about 30 min was performed by spraying with ambient water. The beans were then drained for two min, weighed to determine the hydration coefficient after blanching and then placed in 14 fluid oz (398 ml) cans. This was followed by different treatments for navy (white) and colored beans. Heated tomato sauce that consisted of 10% (w/v) tomato puree, 9% (w/v) sugar, 2% (w/v) salt, 2% (w/v) Colflo67 starch in 1 L of deionized water, was added to each can of navy beans allowing a headspace of about 10 mm. For colored beans, brine solution, which was a heated mixture of 1% salt (w/v) and water was used instead of tomato sauce. The cans were then sealed under atmosphere steam with a can sealer and processed at 121°C for 40 min for navy or 20 mins for colored beans at 4 rev min^{-1} using a 2402 Multimode R&D Retort (Allpax Products, LLC, Covington, LA, USA). Cooling in cold running water for 20 min at 4 rev min^{-1} was performed and the cans were then stored in a dry ambient store for at least 2 weeks before assessing the processing quality.

Data collection

a) MSU and CIAT Uganda

Data were collected on percentage-soaked weight, hydration coefficient and then visual assessments were made on the canned beans. The percentage-soaked bean weight (SBW, g) which is the weight of a bean sample after soaking in cold and then hot was recorded. This weight is the measure of both the weight of water and weight of total solids in the sample.

$$\text{SBW}=\frac{\text{Weight of soaked beans}-\text{Fresh weight (g)of beans equivalent to 90 solid (weight for canning)}}{\text{Weight of soaked beans (g)}} \times 100$$

The hydration coefficient (HC) was calculated as the ratio of two masses of beans as;

$$\text{HC} = \frac{\text{Weight of soaked beans (g)}}{\text{Fresh weight (g)of beans equivalent to 90 g of solid}}.$$

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For visual assessments, the brine and seeds were poured in separate plates and assessed for color, appearance, brine clarity, bean splitting and free starch/clumps using 1 to 5 rating scale (Table 2). A single score for overall appearance was recorded considering all the above-mentioned quality traits [17, 20]. This method made it easier to handle many samples. However, for the 2016 harvest, a 1-7 scale was used to rate each quality trait separately where: 1 = Unacceptable, 2 = Very bad, 3 = Bad, 4 = Fair, 5 = Good, 6 = Very good and 7 = Excellent. The 1-7 scale was used as it was found to be more informative since this trial was for confirmation [17]. Nonetheless, a 1-5 is recommended because there are less categories for raters to decide on, and they are more likely to use the full scale. Five to fourteen people visually rated the canned beans at both MSU and Kawanda, respectively and the averages were obtained for analysis. The visual quality assessment, which is also referred to as the processing quality index (PQI) is assessed subjectively by a trained panel of judges, typically on a 7-point hedonic scale. Using the PQI, six variables are considered and each is weighted for importance: (1) overall appearance, (2) splits, (3) clumps, (4) cooking broth viscosity, (5) cooking broth extruded starch and (6) seed shape, color and size [21].

b) LRDC-Canada

Data were collected on hydration coefficient after soaking (HCS), hydration coefficient after blanching (HCB), drain weight (%), matting (clumping), appearance, seed color, seed texture and the cooking quality. For HCS, a predetermined seed weight (that is, seed solids) based on the bean market class was soaked for 16 hrs in deionized water at room (21°C) temperature. The HCS was determined as: $\frac{\text{Weight of soaked beans (g)}}{\text{weight of dry seed (g)}}$.

For HCB, soaked seeds were blanched for 3 min at 93°C and HCB was determined as: $\frac{\text{seed weight after blanching (g)}}{\text{weight of dry seed (g)}}$.

To measure drained weight (%), colored bean seeds were processed at 121°C at 4 rpm for 20 min in brine while Navy bean seeds were processed at 121°C at 4 rpm for 40 min in tomato sauce. The can content was weighed and the drained weight of bean seed was determined after washing in tap water on an 8-mesh screen (Tyler series) positioned at a 15° angle. Percentage drain weight was determined as: $\frac{\text{weight of bean seed after canning (g)}}{\text{weight of can content (g)}} * 100$.

Drain weight of 60% or higher was acceptable as indicated that 60% of the can content was bean seed. Matting (clumping) and appearance of seeds were

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assessed on a 1 to 4 scale, where 1 = none, 2 = trace, 3 = slight, 4 = moderate for matting, and 1 = excellent, 2 = good, 3 = acceptable, 4 = poor for appearance.

The L* (light-dark), a* (red-green) and b* (yellow-blue) attributes of color were measured on dry and processed (canned) seed using a CR-410 Chroma meter (Konica Minolta Sensing Americas, Inc., Ramsey, NJ, USA). One hundred grams of processed bean seed were used to determine color after canning. Texture (firmness), measured in kg force 100 g seed^{-1} was determined by placing 100 g of washed drained bean into a standard shear compression cell (CS-1) of Texture Measurement System-Touch (TMS-Touch, Food Technology Corp., Sterling, VA, USA) and shearing them using a load cell of 255 kg force at a rate of 0.83 cm sec^{-1}. Comparison was then made with the check varieties.

Cooking quality assessment was conducted to determine hard seeds and partially hydrated seeds. Two hundred seeds per sample were weighed and soaked in stainless steel beakers using deionized water for 16 hrs at room temperature (21°C), drained and reweighed. Deionized water was heated in a blancher (steam cauldron) to 95°C prior to cooking the seed samples in the beakers for 20 min at 95°C. The seeds were allowed to cool to about 50°C and drained. The weight of seeds after cooking was recorded per sample. The hydration coefficients before $\left(\frac{\text{Weight of soaked beans (g)}}{\text{weight of dry seed (g)}}\right)$, and after cooking $\left(\frac{\text{Weight of cooked beans (g)}}{\text{weight of dry seed (g)}}\right)$ were determined. The number of hydrated and partially hydrated seeds before and after cooking were counted to determine percentage hard-seed and percentage partially hydrated seed.

Data analysis

Data collected by MSU and CIAT Uganda were subjected to analysis of variance (ANOVA) in Genstat software, release 19.1 [22] using ANOVA, REML or regression statistics model. The design was orthogonal for all variables; hence, the output was generated by ANOVA model. Correlations between variables were analyzed in the same software using mean data. Broad sense heritability (H^2, repeatability) was calculated on entry mean basis as: $H^2 = \frac{VC_G}{VC_G + VC_{e/r}}$ where, VC = variance component, G = genotype, e = error and r = number of replications. In the case of LDRC, the data were subjected to Proc Mixed of SAS (version 9.3) for modified augmented design. Least significant difference (LSD (0.05)) was derived by Dunnett's Test in Proc Mixed to compare an entry mean with a check cultivar.

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RESULTS AND DISCUSSION

In addition to other traits, the processing quality index (PQI), texture and washed drained weight of canned bean were captured to identify differences among the evaluated genotypes. The above-mentioned three variables have been shown to be most useful for selecting superior genotypes for canning quality [23] and were thus emphasized in this study.

Analysis of variance for canning quality traits observed at Kawanda and MSU laboratories

There were significant differences (P≤0.05) for most traits: hydration coefficient, moisture content, 100 seed weight and visual quality traits after canning among the genotypes (Table 3). Repetition effects were significant (P≤0.01) for all variables for the 2015 harvest evaluated at the two laboratories: CIAT and MSU. The confirmation trial (2016 harvest at Kawanda only) showed that replication effect was only significant in two attributes of visual quality (splitting and clumping).

Replications were made to obtain reliable data. The same seed lot was used in the first two evaluations that were conducted in two laboratories and a different seed lot was evaluated as a confirmatory trial in one of the laboratories. The repetition effect was significantly different in all variables, possibly because the seeds were stored for about a year prior to the second evaluation, and visual quality rating was also carried after different storage periods: 14 and 30 days. Repetition effect in the confirmatory trial was only significant in two visual quality traits: splitting and clumping implying that there was less variation due to external factors in the data. Uniformity in canning procedure and consistent quality determined by visual rating was suggested as a necessity for a variety to be commercially successful because bean genuineness is assessed [24]. Although genotypes only significantly (P ≤ 0.001) differed in moisture content, weight of 100 seeds, hydration coefficient in the first two evaluations, significant differences (P ≤ 0.001) were observed in all traits except in moisture content in the third evaluation. The repeatability (broad sense heritability) for hydration coefficient and visual quality assessment for each attribute (and the averaged value) were generally high (> 0.6) except in color (Table 3). This indicated high potential to reliably select for genetic variation. This variation is vital for genetic gain during crop improvement because it creates a wide genetic base that is important for selection [25].

Hydration Coefficient (HC) of common bean genotypes during evaluation for canning quality

There were significant differences (P≤0.05) among the laboratories and among lines for HC (Table 3). The high mean values (1.9 to 2.1) for this trait indicated that majority of the genotypes had a relatively high HC. The values varied between 1.6 and 2.3 at Kawanda (2015 and 2016), 1.0 and 2.2 at MSU (Annex 1). A value of 1.8 is acceptable by the canning industry because soaking uncooked beans normally causes a mass increase of 80% [18, 23]. A high HC is preferred because such beans produce greater can quantity. A moderate positive correlation that existed between hydration coefficient (HC) [r = 0.53***] and 100 seed weight (Table 4) showed that larger beans absorbed proportionally more water during soaking. Out of 67 large (SW100 ≥ 35.0 g) and 54 small (SW100 < 35.0 g) seeded genotypes, 75% and 37%, respectively, had consistent HC of ≥2 (Data not shown). A high HC reduces cooking time and causes a quicker germination when seeds are planted, making it very desirable in the industry [8]. In general, of the 121 genotypes, 87 lines (72%) had HC greater than 1.8 in all the three evaluations, which indicated a high potential of finding industry acceptable genotypes based on further characterisation. Consistent superiority (HC >2.1) in this trait was observed in 27% of the lines; the exceptional ones were in VTTT923/10-3, GASIRIDA, NABE18, NABE19, K132 (CAL96), CODMLB001 and NABE26C, NUA8, KK8 and MAC44 (Annex 1).

Considering data from LRDC-Canada, all large seeded varieties except for NUA45, had HCS and HCB above 1.8 indicating potential for canning (Annex 2). The varieties NABE29C and VTTT923/10-3 had HCS of 2.2 higher than the large-seeded check AAC Cranford (2.1) and equal to AAC Expedition (2.2). Four large seeded varieties: NABE11, VTTT923/10-3, NABE20 and KK8 had HCB of 2.4 greater than all the checks. Nine medium seeded varieties had HCS less than 1.8 while only one NUA689 had HCB less than 1.8. Fourteen small seeded varieties had HCS less than 1.8 while only two, VAX4 and TU had HCB less than 1.8 (Annex 2).

Visual quality/processing quality index (PQI)

Appearance of seeds was assessed on a 1 to 4 scale at AAFC-LRDC, Canada where, 1 = excellent, 2 = good, 3 = acceptable, 4 = poor) compared to 1-5 and 1-7 scales that were used in Kawanda and MSU.

Based on canning tests conducted on the 2015 trial at Kawanda and MSU, the mean scores ranged from 2.5 to 5.1 and 15.7% of the lines scored above the mean. Out of the 87 lines, which were consistently superior in HC, 33 lines (37.9%)

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Volume 22 No. 8
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had average to excellent visual quality (Figures 1 and 2). In the 2016 trial, 13% of the lines were rated very good to excellent, 36% were rated good to very good (Figure 3). Although not very strong, HC positively correlated to visual canning score [r = 0.26***] (Table 4), which showed that genotypes with high values of HC tended to have good visual quality respectively. The following four large and one small seeded genotypes: MAC44, SAB659, NABE12C, NABE21 and VAX5, respectively, combined high (≥2) HC with superior visual canning quality across the two seasons at the two laboratories (2015 MSU and Kawanda, and 2016 Kawanda) (Annex 1). These were rated 4/5 and 6/7 on a 5- and 7-point scale, respectively, signifying very good to excellent canning quality basing on appearance, brine clarity, bean splitting and absence of starch/clumps in 2015 and 2016. About 9.9% of genotypes had higher scores than the check genotypes, MEXICO142, Awash1 and Awash Melka whose visual scores were 2.0/3.1, 1.0/3.8 and 2.0/3.3, respectively, in the first two evaluations. All these checks are white beans and only one genotype of the same seed type, Michelite (3.0/3.6), exhibited a slightly better quality.

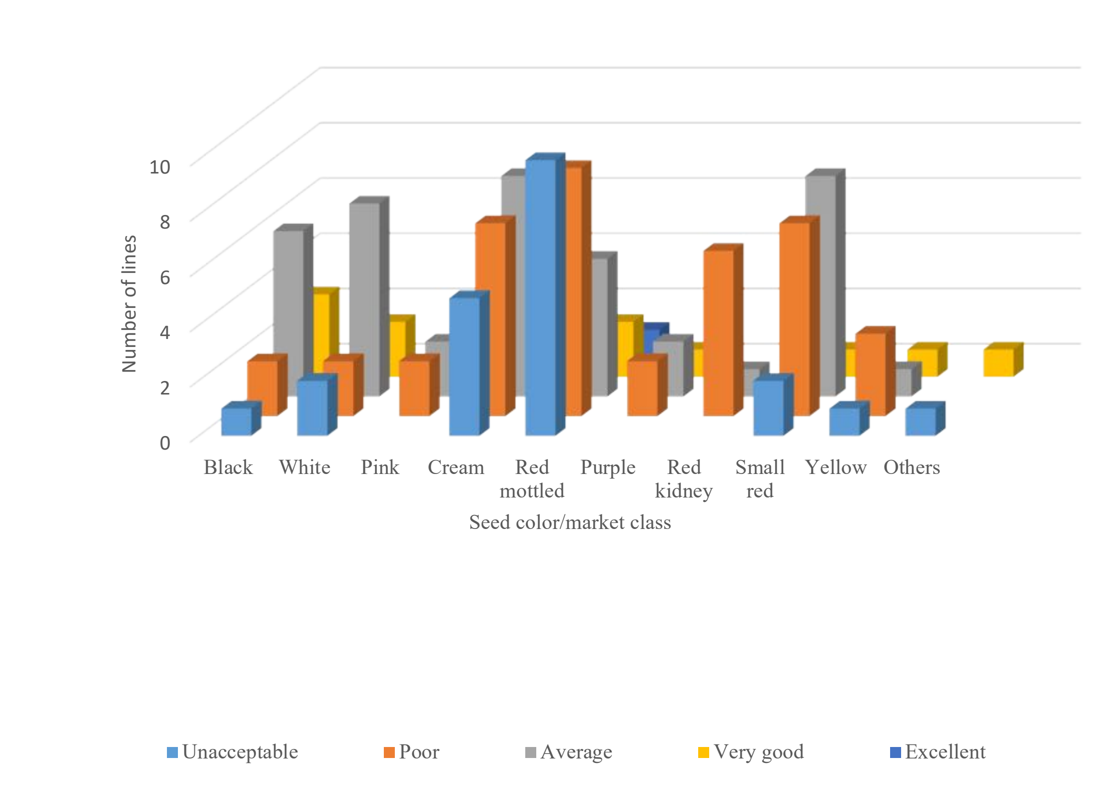

Figure 1: Visual assessment of 121 beans lines (season 2015) after canning at MSU

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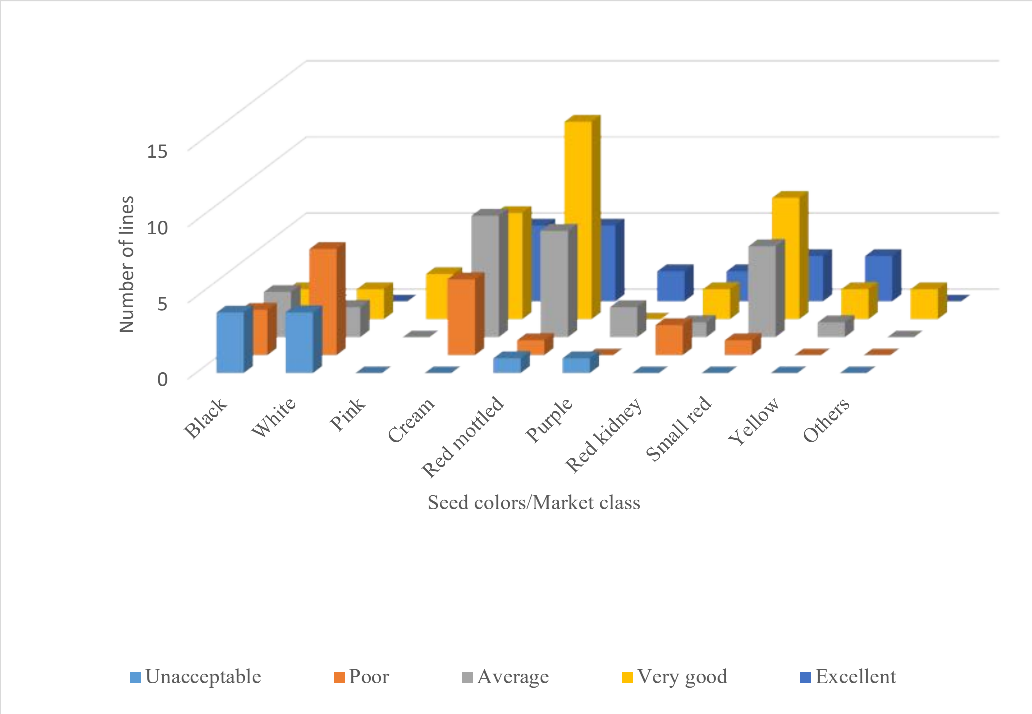

Figure 2: Visual assessment of 121 bean lines (Season 2015) after canning at Kawanda

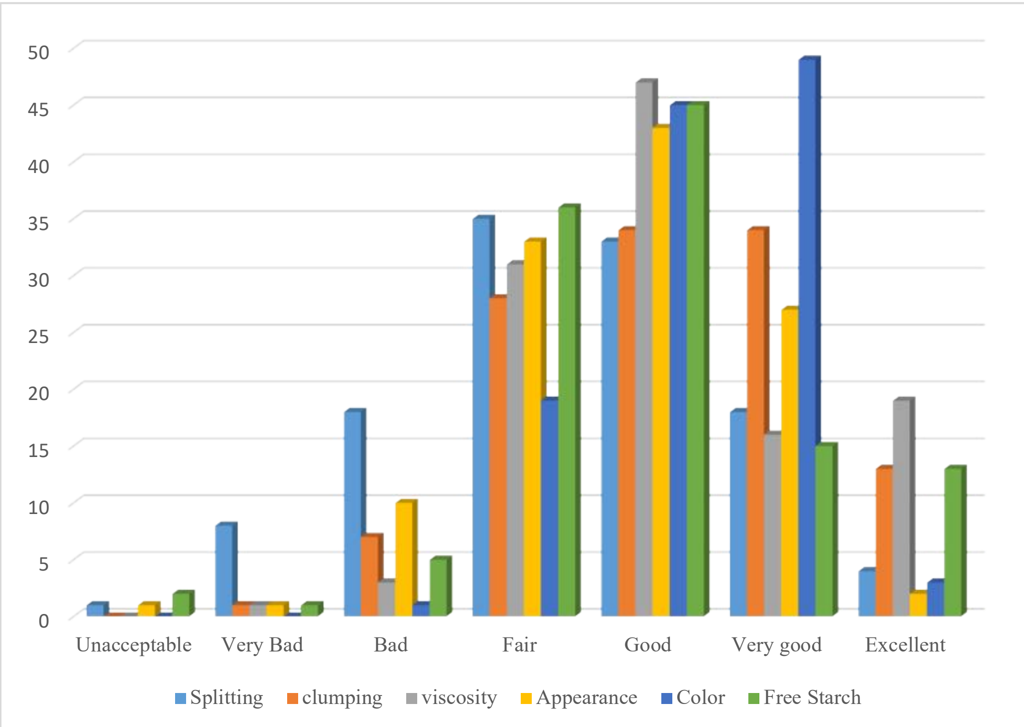

Figure 3: Canning quality variables assessment on 118 genotypes based on 7-point hedonic scale planted at Kawanda Season 2016

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Among the 134 lines evaluated in Canada, 18 were large seeded with the majority being of red mottled grain market class, 60 were medium seeded with the majority being of red mottled grain market class and 53 were small seeded with a number of them being white, black or red in color. Results showed that all the large seed varieties with the exception of G16157 had excellent to good appearance after canning (Figure 4) and were more superior to the checks. There was trace to no matting among these varieties. All the medium seeded varieties had excellent to good appearance after canning except GLP2 (Figure 4). Most of the small seeded varieties had good to acceptable appearance after canning, however, Maharage Soja had a poor appearance (Annex 2). Several genotypes were more superior to the above-mentioned check genotypes across the three laboratories (Table 5).

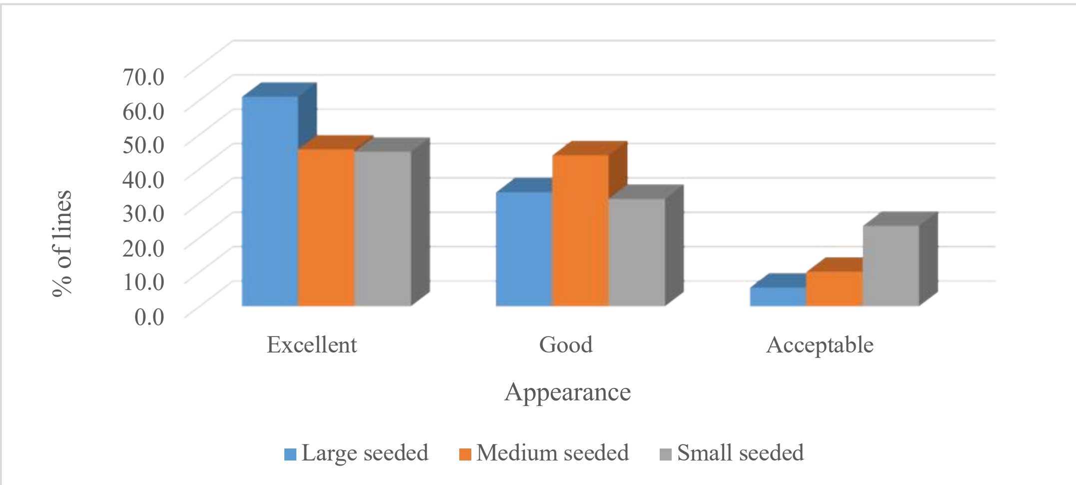

Figure 4: Appearance of a collection of 134 lines of different seed sizes (Season 2017) after canning at LRDC

Several genotypes expressed excellent/ very good canning quality based on color retention, appearance, brine clarity, bean splitting and absence of starch/clumps. The superior lines belong to several market classes and could have wide acceptability if promoted for canning. An old genotype MEXICO142 highly utilised in the canning industry in Kenya in the past years [10] was on average rated between fair and good. Though not white seeded like MEXICO 142, the genotypes MAC44 (red mottled climber), NABE12C/ SUG35 (cream seeded climber), BIHOGO (yellow seeded bush bean), VAX5 (small cream seeded bush bean), KK8 (red mottled bush) and NABE29C (small red seeded climber) were consistently very good/ excellent in visual quality. This showed the potential that exists in other non-white market classes, but also recognised a need for breeding for more white beans that are not only good for canning but also resilient in farmer fields. The genotypes Awash1 and Awash Melka that were also on average rated fair/ good in visual quality were among genotypes with the highest canning quality in a study carried out in Ethiopia [8]. They were evaluated together with other three white bean genotypes: Argene, Omer and Chercher and it was concluded that they together with Argene were suitable for canning. This study had a larger set of lines and MAC44, NABE12C/SUG35, BIHOGO, KK8, SAB659 and NABE21 were consistently superior. However, none of these are white and thus cannot feed in the current market segment. Two white beans: Michelite and CAB2 exhibited a relatively similar canning quality to these check lines. Small seeded white beans that are significantly better than the current ones demanded by the market were absent and thus breeding efforts need to be directed to this area.

Studies have been done on several market types: black beans [16]; kidney beans [26, 27] and white beans [11, 8, 9, 10, 28, 29] which seem to remain the most popular in canning industry. In addition to white beans, other major market classes including red mottled, small reds, yellows and sugar beans are widely consumed in east and central Africa [30]. Beans belonging to these market classes like Masindi yellow short, Masindi yellow long, VAX2, MEXICO142, MAC44, KK8, SAB659, NABE29C, NABE8C, NABE21, et cetera, that retained their colors during canning process, and were superior in all or most of the other traits have untapped potential in this region if promoted, improved or used as parental genotypes for breeding. In addition, the superior lines are of both bush and climbing bean types indicating a broader potential for adoption by farmers if promoted. Growth habit and seed type are some of the key traits that have potential effect on connecting farmers/ seed producers to the market. These need to be considered early in the breeding pipelines to produce lines relevant to the market. Overall, this study showed the presence of genotypes possessing good canning quality in the germplasm popular in east and central Africa.

Drained weight and overall canning quality at LRDC-Canada

A drained weight of ≥60% is acceptable and it indicates that ≥60% of the can content was bean seeds [18]. All large, seeded genotypes except for G16157 and NUA45 were acceptable although none outperformed the checks. Similarly, all small seeded genotypes except for Roba1, Maharage soja and NABE6 and all medium sized varieties except for GLP2, NUA689 and KATB9 were acceptable (Annex 2). There was no association [r = -0.03, ns] between washed drained weight (WDW) and weight of 100 dry bean seeds (SW100) (Table 4). As noted above, large, medium and small seeded genotypes performed similarly well in this trait. Test varieties were compared against industry checks and in summary the varieties NGWINXCAB2, NABE21, CODMLB001, NABE12C, Michelite, Awash1 and SELIAN97 (red kidney) exhibited excellent canning qualities with respect to

HC, drained weight, matting and appearance from tests conducted at LDRC (Annex 2).

Texture of common bean genotypes at LRDC-Canada

Variability in texture ranged from 19.3 in CNF5520 to 114.7 in NUA689 with a mean of 49.9 kg force per 100 g processed seed (Annex 2), which indicated that majority of the genotypes were soft. The optimum canning requirement of firmness/texture is 55-65 kg force per 100 g processed seed based on processors and consumer preferences [31] and 91% of the genotypes met this requirement. However, beans should soften during processing, but not to disintegrate the bean contents [31]. Other studies report texture ranges of 38.5 to 48.7 for navy bean and 59.1 and 89.9 for small white [31, 32] which are comparable to the values obtained in this study. Compared to the check genotypes, only CNF5520 was lower than AAC Cranford and AAC Expedition, and 14 other genotypes were lower than AC Black Diamond. The genotype CNF5520 was significantly ($P \leq 0.05$) different from AAC Cranford while NABE9C and MEXICO 54 did not significantly differ ($P \leq 0.05$) from AAC Cranford and AAC Expedition respectively (Annex 2). Texture is thought to be influenced by seed coat thickness among other traits, thus beans with thin seed coats like the navy type tend to have low texture to withstand the canning process [32]. For this reason, the type is canned in tomato sauce for acceptable texture and appearance [33] and a higher texture value of 72 kg force per 100 g processed seed is the industry standard for navy bean [31]. Texture was significant ($P \leq 0.001$) and negatively associated [$r = -0.26$ to -0.46] with all the different hydration coefficients (Table 4), which showed that beans with poor soaking ability required more force to penetrate. In addition, the higher the texture, the lower the SW100, appearance and matting but only the latter had a significant [$r = -0.23^{**}$] association (Table 4). This indicated that beans with low texture (firmness) tended to clump easily.

Color of dry and canned beans at LRDC-Canada

Color is an attribute of beans that influences the market based on consumer preference [30]. The color of dry and cooked beans is measured visually or by a chromameter using L^*, a^*, b^* values. The L^* indicates "light-dark" with higher values for lightness; a^* indicates "red-green" with positive values for redness and negative values for greenness; and b^* indicates "yellow-blue" with positive values for yellowness and negative values for blueness [34]. Based on the importance of color to the market, a positive correlation between the dry and the cooked bean is important. In this study, the positive and strong significant (≤ 0.001) correlations existed in the L^*, a^*, b^* values of dry and canned beans (Table 4), which showed that majority of the genotypes retained their color during the canning process.

However, compared among the three categories, beans with high positive b* values (yellowness) tended to lose more color during canning since its correlation [r = 0.63] was lower than the 0.89 and 0.80 obtained for L* and a* (Annex 2). Overall, the following 14 genotypes: RANJONOMBY, CAB2, RWV3006, G90, SAB712, CNF5520, VCB81013, Awash Melka, RWV3316, KATSW-12, KATSW-9, KATSW-10, UBR (92)25 and Awash1 were superior to all the three checks, AAC Expedition, AAC Cranford and AC Black Diamond in maintaining high L* and b* values in both dry and cooked beans (Annex 2). These could be used as parental lines for improvement of this trait but most genotypes including those previously identified visually retained color during canning.

Cooking quality of dry bean lines evaluated at LRDC-Canada
Thirty-seven genotypes (29%) were superior to the industrial checks in regard to having no or negligible proportions of hard seed after a 16 hr soak at 21°C and partially hydrated seed after a 16hr soak at 21°C (Table 6). Thirty-two lines (24%) had HC less than 1.8 after a 16hr soak at 21°C but all 130 lines had HC >2 after 20 min cooking time at 95°C. Only three lines: NUA689, RWV3006 and RWV3316 had >1% hard seed after cooking for 20 min at 95°C. Eleven lines remained partially hydrated after 20 min of cooking at 95°C. Eleven lines including BAT332, VAX5, UBR(95)25, KATSW9, KATSW10, KATSW12, NABE6, Kanyebwa, ECAPAN01, NABE29C and Masindi Yellow had good cooking qualities (Table 6).

CONCLUSION

There was diversity among genotypes used in this study which can be further exploited to improve canning quality traits of common beans. There were no identified small white bean genotypes superior to the three small white beans popular in the canning industry in this region suggesting that more breeding effort is needed for this market segment. Nonetheless, the several identified genotypes could be promoted for canning purposes to capture the diverse market preferences in color that exist in Africa. Many of these genotypes are already with the farmers and their adoption by the processors could open a new market for the farmers, thereby increasing their income. Considering the three key traits for measuring canning quality [23], texture was weakly, non-significantly and negatively correlated to appearance. Similarly, appearance expressed weak negative non-significant correlation with washed drained weight. These indicated that beans with high firmness tended to exhibit better appearance and that better appearance was associated with high drained weight. While both were expected favorable associations, they were non-significant showing the need to phenotype for all the traits during evaluation.

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 22 No. 8
October 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Global Affairs Canada (GAC), the Swiss Agency for Development and Cooperation (SDC) that support the Pan Africa Bean Research Alliance (PABRA) and the Bill and Melinda Gates Foundation (BMGF) that supported the Tropical Legume III and The Accelerated Varietal Improvement and Seed Delivery of Legumes and Cereals in Africa (AVISA) projects. We thank T. Reid, S. Kinnee and C. Campbell for technical assistance with seed quality assessments in the Bean Pilot Plant at LRDC-Canada.

https://doi.org/10.18697/ajfand.113.21630

Table 1: Characteristics of bean genotypes studied

Group	%
Use	
Released varieties	65.7
Parental/ breeding lines	28.4
Landraces	6.0
Growth habit	
Bush	88.1
Climbers	11.9
Seed size	
Medium	45.7
Small	40.3
Large	14.0
Seed color	
Red mottled	20.6
Speckled/cranberry/sugar	19.9
Red	19.2
White	13.5
Black	9.9
Yellow	5.0
White	5.0
Pink	4.3
Purple/kablanketi	2.8

ajfand SCHOLARLY, PEER REVIEWED
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PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 2: Five-point scale used to rate appearance of 121 bean genotypes after canning for four weeks

	Score	Bean Splitting	Note	Brine Clarity	Free Starch/Clumps	Color
Excellent appearance	5	None	90% of seeds intact	Very Clear	Very Little starch/Clumps	Excellent color (exceeds industry standard)
Very good appearance	4	Moderately Intact	70-89% of seeds intact	Moderately Clear	Moderately little starch/Clumps	Very good color (meets industry standard)
Average appearance	3	Average	60-69% of seeds intact	Neither Clear or Cloudy	Neither Little or Much	Average Color
Poor appearance	2	Moderately Broken	Seeds badly split but holding together	Moderately Cloudy	Moderately Many/Big Starch/Clumps	Poor color (a little darker or lighter than industry standard)
Unacceptable appearance	1	Severe	Seeds blown apart	Very Cloudy	Very Big Starch/Clumps	Unacceptable color (a lot darker or lighter than industry standard)

ajfand SCHOLARLY, PEER REVIEWED
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October 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 3: Mean squares for canning quality traits for the evaluation at Kawanda and Michigan State University (MSU)

		Seed lot_1				Seed lot_2: Confirmation trial							
SOV	DF	MC (%)	HC	100SW	VC	MC (%)	HC	Splitting	Clumping	Viscosity	Appearance	Color	Free Starch
Repetition	1	382.97***	0.59***	782.62***	44.49***	0.20	0.004	7.26***	3.65*	0.44	1.04	0.19	0.00
Genotype	120 (116)	1.30*	0.08***	198.13***	1.2	0.50	0.0213***	3.00***	2.59***	2.64***	2.09***	1.21***	2.63***
Residual	120 (116)	0.86	0.03	20.22	1.05	0.47	0.006	0.62	0.69	0.82	0.83	0.66	0.65
Total	241 (233)	2.66	0.06	110.87	1.3	0.46	0.014	1.72	1.57	1.65	1.33	0.89	1.50
Repeatability (H^2)			0.63		0.90		0.72	0.79	0.73	0.69	0.60	0.45	0.75

SOV=source of variation, DF=degrees of freedom, MC=moisture content, HC= hydration coefficient, 100SW =100 seed weight, VC=visual canning score; *, **, *** = P ≤ 0.05, 0.01, 0.001 respectively, H^2 = broad sense heritability (repeatability)

Table 4: Correlations of canning quality traits at Kawanda (1), MSU (2), Kawanda-confirmation (3) and LRDC-Canada

Kawanda and MSU

	Hydration coefficient_1_2_3	**Visual Canning score_1_2_3**	**Moisture content (%) _1_2**	**SW100_1_2**
Hydration coefficient_1_2_3	-			
Visual Canning score_1_2_3	0.26**	-		
Moisture content (%) _1_2	-0.31***	0.05	-	
SW100_1_2	0.53***	0.20*	-0.31***	-

LRDC-Canada

	Texture	**HCS**	**HCB**	**HCbC**	**HCaC**	**Appearance**	**Matting**	**SW100**	**WDW**	**Dry L***	**Dry a***	**Dry b***	**Canned L***	**Canned a***
Texture	-													
HCS	-0.46***	-												
HCB	-0.45***	0.81***	-											

HCbC	-0.46***	0.94***	0.67***	-									
HCaC	-0.26**	0.49***	0.70***	0.40	-								
Appearance	-0.11	-0.06	-0.17*	-0.07	-0.32***	-							
Matting	-0.23**	-0.07	-0.07	-0.03	-0.02	0.20*	-						
SW100	-0.14	0.15	0.34***	0.05	0.56***	-0.23**	-0.13	-					
WDW	-0.28**	-0.03	0.12	-0.05	0.31***	-0.16	0.20*	-0.03	-				
Dry L*	-0.38***	0.11	-0.03	0.21*	-0.02	0.04	0.16	-0.22*	-0.03	-			
Dry a*	0.11	0.04	0.25**	-0.05	0.36***	-0.19*	-0.23**	0.51***	-0.15	-0.43***	-		
Dry b*	-0.21*	0.26**	0.16	0.32**	0.19*	-0.07	-0.06	0.05	-0.12	0.66***	-0.01	-	
Canned L*	-0.42***	0.12	-0.07	0.22*	-0.14	0.07	0.17*	-0.23**	-0.15	-0.89***	-0.41***	0.45***	-

Canned a*	0.21	0.03	0.26***	-0.08	0.35***	-0.22*	-0.29***	0.53***	-0.18*	-0.55***	0.80***	-0.05	-0.56***	-
Canned b*	-0.40*	0.19*	0.08	0.24**	0.06	-0.02	0.01	0.02	-0.23**	0.80***	-0.11	0.63***	0.88***	-0.16

Number of observations: 121 (Kawanda and MSU) and 133 (LRDC-Canada); *, **, *** = P ≤ 0.05, 0.01, 0.001 respectively for two-sided test of correlations different from zero, SW100 = Weight of 100 seeds. HCS = hydration coefficient after soaking, HCB = hydration coefficient after blanching, HCbC = hydration coefficient before cooking, HCaC = hydration coefficient after cooking, Dry = dry bean, Canned = canned bean, L* = light-dark, a* =red-green, and b* = yellow-blue attributes of color

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 22 No. 8
October 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 5: Genotypes with very good to excellent visual appearance based on a hedonic scale

Genotype	Seed color	2015 Kawanda 1-5 Score	2015 MSU 1-5 score	2016 Kawanda 1-7 Score	Scores at LDRC (1-4 scale)
MAC 44	Red mottled	4	4.0	6.5	2.1
BIHOGO	Yellow	4	4.3	6.2	1.0
NABE12C	Cream	5	4.6	6.5	1.1
VAX5	Small cream	4	4.1	6.0	1.9
NABE8C	Small red	4	Na	6.0	2.6
Masindi yellow short	Yellow	4	2.3	6.7	2.1
SAB 659	Red mottled	5	4.1	6.2	1.1
RWV2887	Cream	5	4.4	Na	2.1
Masindi yellow long	Yellow	5	1.4	6.3	1.8
KK8	Red mottled	4.9	Na	6.3	1.6
MEX142 (Check)	Small white	5	3	6	1.9
AWASH MELKA (Check)	Small white	2	3	3	2.1
AWASH 1 (Check)	Small white	1	4	3.8	1

Na= data not available
1-4 scale: 1 = excellent, 2 = good, 3 = acceptable, 4 = poor
1-5 scale: 1 = Unacceptable Appearance, 2 = Poor Appearance, 3 = Average Appearance, 4 = Very Good Appearance, 5= Excellent Appearance
1-7 scale: 1 = Unacceptable, 2 = Very bad, 3 = Bad, 4 = Fair, 5 = Good, 6 = Very good and 7 = Excellent

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AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 22 No. 8
October 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 6: Cooking quality evaluation of selected dry bean genotypes sent in 2018 from CIAT Uganda to LRDC-Canada

Genotype	16-hour soak at 21°C			20 min at 95°C		
	Hard Seed (%)	Partially Hydrated Seed (%)	HC	Hard Seed (%)	Partially Hydrated Seed (%)	HC
G16157	0.5	2.8	2.1	0.0	0.0	2.2
BAT332	0.0	0.0	2.1	0.0	0.0	2.2
NABE11	0.0	2.9	2.1	0.0	0.0	2.4
NABE5	0.0	3.1	2.1	0.0	0.0	2.4
NABE21	0.0	4.6	2.1	0.0	0.0	2.4
NABE12C	0.0	8.9	2.1	0.0	0.0	2.4
VAX5	0.0	0.0	2.2	0.0	0.0	2.3
GITANGA	0.0	7.4	2.1	0.0	0.0	2.4
KATX56 (KATB56)	1.0	20.6	2.1	0.0	0.0	2.4
NGWAKU NGWAKU	0.0	3.1	2.2	0.0	0.0	2.4
FLOR DE MAYO	0.5	4.1	2.1	0.0	0.0	2.3
NABE9C	2.0	5.6	2.2	0.0	0.0	2.5
KATB1	0.0	5.3	2.2	0.0	0.0	2.3
NABE2	2.0	3.1	2.1	0.0	0.0	2.2

Cornell 49-242	0.0	2.4	2.1	0.0	0.0	2.2
G21212	0.5	0.8	2.2	0.0	0.0	2.3
Mexico142	0.5	6.1	2.1	0.0	0.0	2.2
UBR(92)25	0.0	1.9	2.0	0.0	0.0	2.2
KATSW9	0.0	0.0	2.1	0.0	0.0	2.2
KATSW10	0.0	0.0	2.1	0.0	0.0	2.2
KATSW12	0.5	0.0	2.1	0.0	0.0	2.2
NABE6	0.0	0.0	2.1	0.0	0.0	2.2
Kanyebwa	0.0	0.0	2.1	0.0	0.0	2.3
NABE20	0.0	6.8	2.1	0.0	0.0	2.4
ECAPAN021	0.0	1.9	2.2	0.0	0.0	2.3
NABE29C	0.0	0.0	2.2	0.0	0.0	2.3
NUA99	2.0	15.3	2.1	0.0	0.0	2.3
NUA59	0.0	15.8	2.1	0.0	0.0	2.3
GLP2	0.0	2.9	2.2	0.0	0.0	2.3
AFR708	1.0	15.1	2.1	0.0	0.0	2.3
NABE17	0.0	11.8	2.0	0.0	0.0	2.3
AB136	0.0	3.1	2.3	0.0	0.0	2.4

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ISSN 1684 5374

RANJONOMBY	0.0	0.0	2.3	0.0	0.0	2.5
MASINDI YELLOW SHORT	0.0	3.4	2.2	0.0	0.0	2.3
MASINDI YELLOW LONG	0.0	0.6	2.1	0.0	0.0	2.4
AKARYOSE	2.0	7.6	2.1	0.0	0.0	2.3
AAC Cranford	1.2	15.3	2.1	0.0	0.0	2.4
LSD	11.2	11.9	0.1	-	0.5	0.0
AAC Expedition	0.6	0.1	2.1	0.0	0.0	2.4
LSD	11.8	12.6	0.1	-	0.5	0.0
AC Black Diamond	23.1	21.3	1.7	0.0	0.3	2.2
LSD	11.8	12.6	0.1	-	0.5	0.0

Hard seed and partially hydrated seed (%): 2% could be cut off but industry prefers 0%. Depends on location. LSD = least significant difference, HC = hydration coefficient. Three check lines were used, AAC Cranford (Main check, 12 replicates, large seeded); AAC Expedition (Secondary check, 5 replicates, medium seeded); and AC Black Diamond (Secondary check, 5 replicates, small seeded)

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ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 22 No. 8
October 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Annex 1. Means of selected genotypes for the canning quality traits (1=Kawanda, 2=MSU, 3=Kawanda: confirmation)

Genotype	MC%-1	MC%-2	MC%-3	HC-1	HC-2	HC-3	Visual score 1	Visual score 2	Splitting-3	Clumping-3	Viscosity-3	Appearance-3	Color-3	Free Starch-3	SW 100-1	SW 100-2	Growth Habit	Market class
Awash 1	14.2	16.3	13.1	1.8	1.8	2	1	4	5	6	5	5	5	5	17.8	19.9	Bush	White
Awash Melka	13.3	16.2	12.5	1.9	1.6	2	2	3	6	5	5	4	6	4	21.1	23.5	Bush	White
BIHOGO	12.2	15.5	12.6	2.1	2.1	2	4	4	6	7	7	6	4	7	30	40.1	Bush	Yellow
CAB 2	13.3	15.5	13.4	1.8	1.7	2	3	3	4	4	7	6	4	7	38	33.7	Climber	White
CODMLB001	12.3	13.6	12.5	2.3	2.2	2.2	5	2	5	6	5	5	5	4	34.5	48.2	Bush	Purple
GLP2 (K20)	12.8	15.6	14.3	2.1	2.1	2.1	5	1	3	5	5	4	5	5	32.7	38.8	Bush	Red mottled
K132 (CAL 96)	12.5	15.5	12.8	2.2	2.2	2.2	4	3	2	4	4	5	6	3	46.7	49.8	Bush	Red mottled
KATB9	12.9	15.3	13.2	2	2	2	5	1	3	5	4	4	5	4	36	40.8	Bush	Small red
KK8	12.3	16	12.3	2.1	2.2	2.3	3	5	7	7	6	6	6	6	40.6	50.9	Bush	Red mottled
MAC 44	12.4	15.3	13.1	2.1	2.2	2.2	4	4	6	7	7	6	6	7	46.4	52.6	Climber	Red mottled
MASINDI YELLOW LONG	13.2	16.4	12.6	2.1	1.4	2.2	5	2	6	7	6	6	7	6	44.1	40.1	Bush	Yellow
MASINDI YELLOW SHORT	14.4	19.3	12	2.1	1.4	2.1	4	1	6	7	6	7	7	7	40	39.7	Bush	Yellow
MEXICO142	13.3	16.5	13.2	1.9	1.9	1.9	2	3	4	5	5	6	6	5	16.2	18.4	Bush	White
Michelite	15.1	19	13.1	1.9	1.8	2	3	4	4	5	5	5	6	5	16.5	18.5	Bush	White
NABE11	12.4	15.8	12.2	2.1	2.1	2.1	3	3	4	5	3	5	6	5	44.8	48.9	Bush	Cream
NABE12C (SUG 35)	12.7	15.5	13.2	2.1	2.1	2	5	5	6	7	7	6	6	7	39.4	52.8	Climber	Cream
NABE18	13.3	15.3	12.4	2.1	2.2	2.2	3	3	5	5	5	5	5	4	43.9	44.9	Bush	Purple mottled
NABE19	12.5	14.9	13	2.1	2.2	2.2	4	2	4	5	4	4	5	4	42.5	42.8	Bush	Red mottled
NABE20	12.4	15.9	12.3	2.1	2.1	2.2	4	4	4	5	5	4	5	4	45.9	42.5	Bush	Pink
NABE21	13.1	15.3	13.1	2.1	2.1	2.1	4	4	6	6	5	6	6	5	32.9	37.9	Bush	Cream
NABE26C	12.4	13.6	12.6	2.2	2.2	2	4	3	5	6	5	5	6	5	35.6	41.3	Climber	Red mottled
NABE29C	11.9	15.5	12.3	2.1	2.1	2	5	3	5	7	7	5	6	5	46.4	56	Climber	Small red
NABE6	13.8	17.3	12.9	1.9	1.8	1.9	2	3	3	4	4	5	6	5	18.2	22.4	Bush	White
NABE8C	13.2	15.4	13	2.1	2	2.1	4	3	7	6	6	6	6	5	58.7	39.1	Climber	Small red

ajfand SCHOLARLY, PEER REVIEWED
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ISSN 1684 5374

NGWAKU NGWAKU	13.1	16	13.6	2.1	2.1	2.1	5	2	5	6	5	6	5	5	46.4	45.1	Bush	Yellow
NUA45	12.7	13.6	13.3	1.8	1.9	2.1	2	2	4	4	4	3	4	4	38.9	52.6	Bush	Red mottled
NUA8	13.4	16.3	11.8	2.1	2.2	2.3	4	2	4	6	5	6	6	5	50.8	56.6	Bush	Red mottled
ROBA-1	14.4	16	13.8	2	1.5	2	3	2	3	4	4	6	6	6	20.6	21.8	Bush	Small cream
SAB 622	13.2	14.5	12.7	2.1	2	2.1	5	2	5	6	6	6	6	5	28.6	44.3	Bush	Dark red kidney
SAB 659	13.8	15.2	12.9	2.1	2.1	2.1	5	4	7	7	5	6	6	6	36.8	52.9	Bush	Red mottled
SELIAN 97	12.9	15.4	13	1.9	2.1	2.1	5	3	4	5	5	4	5	5	30.1	36.1	Bush	Dark red kidney
VAX2	13.4	16	13.5	2.1	2.1	2.1	3	1	6	6	6	6	7	6	22.8	29.4	Bush	Cream
VAX5	13.8	20.9	13.4	2.1	1.8	2.1	4	4	6	6	6	6	6	6	17.8	24	Bush	Small cream
VTTT 923/10-3	13.3	13.4	12.5	2.1	2.2	2.2	2	3	4	5	4	4	6	4	44.6	50.4	Bush	Cream
ZEBRA	13.3	15.3	12.7	1.9	2	1.9	3	3	6	7	7	6	6	7	23.8	33.1	Bush	Cream
Minimum	11.9	13.4	11.7	1.6	1	1.6	1	1	0.8	2	2	0.9	3	1	14.1	18.2		
Maximum	15.1	21.1	14.3	2.3	2.2	2.3	5	4.9	7.2	7.1	7	7.1	7	7	58.7	56.6		
Mean	13.3	15.8	12.8	2	1.9	2.1	3.3	2.5	4.2	4.9	4.9	4.5	5.1	4.6	32.8	36.2		
CV%			5.3			3.7			18.9	16.9	18.4	20.2	16	17.5				
S.e.			0.48			0.05			0.55	0.59	0.64	0.64	0.57	0.57				
L.s.d.(0.05)			1.4			0.2			1.6	1.6	1.8	1.8	1.6	1.6				

MC% = Moisture content, HC = Hydration coefficient, SW100 = Weight of 100 dry bean seeds, CV% = coefficient of variation, S.e. = standard error of the mean, L.s.d = least significant difference

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ISSN 1684 5374

Annex 2. Canning quality evaluation of selected dry bean genotypes sent in 2018 to LRDC Canada from CIAT Uganda

Genotype	Entry	SW100 (g)	Seed solids for canning (g)	HCS (16 hr at 21°C)	HCB (3 min at 93°C)	Drained Wt. (%)	Matting (1 to 4)	Appearance (1 to 4)	Dry color			Canned color			Texture (Firmness) (kg force)
									L*	a*	b*	L*	a*	b*	
AKARYOSE	134	31.3	86	2.2	2.3	64.2	1.1	1	59.9	7.9	39.9	31.9	10.8	14.7	46.4
AND 1062	71	27.3	86	2.1	2.3	63.2	1.1	1	44.8	18.4	8.2	29.5	11.2	11.4	35.5
AND277	86	39.5	86	1.9	2.3	61.6	1	1	32.1	16.8	4.4	22.1	11.4	5.4	67.6
Awash 1	52	17.1	90	1.9	2	62.4	1	1	77.8	4.7	20.8	52.2	6	18.6	56.2
Awash Melka	59	21.8	90	1.9	2.2	67	1	2.1	81.3	4.8	21.8	47.7	5.8	17.3	48.3
BAT332	2	14.4	90	2.1	2.2	63.5	1.1	1.9	46.2	14.4	18	22.4	8.8	6.3	62.5
BIHOGO	37	33.2	86	1.6	2	64.5	1	1	53.4	18.6	37.3	25.6	11.6	10.3	67.5
BISERA	108	45.4	86	2	2.3	62.6	1	1	38.5	23.5	9.4	29.2	14	12	36.3
CAB 2	63	25.5	90	2	2.2	66.4	2	1.2	92.1	2.5	17.9	50.2	5.1	16.3	32.7
CAL96	102	39.8	86	2	2.3	61.4	1	2.8	38.8	23.9	10	30	12.8	12.1	49.8
CNF5520	60	22	90	2.1	2.2	67.3	3	3.2	82.1	3.4	20.7	49.5	5.4	16.4	19.3
CODMLB001	72	32.2	86	2.1	2.4	63.5	1	2	40.4	11.4	6.9	29.7	13.1	12.5	58.8
CODMLB033	87	30	86	2.1	2.3	61.6	1	1	45.5	22.1	12.2	26.7	12.8	10.7	59.8

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ECAPAN021	76	23.1	90	2.2	2.3	66.8	1	1.9	28.3	13.8	3.8	22.3	12.2	5.8	42.3
G 90	56	18.6	90	1.9	2.1	63.7	1.9	3	84.3	3	16.6	50.1	5.5	17.2	34.4
G16157	1	40.1	86	2.1	2.2	58.9	1	3.1	49.8	13.5	19.3	31.5	11.2	12.2	37
G21212	48	22.9	93	2.2	2.3	69.4	1	2.1	28.3	0.7	0.1	21.7	6.6	3.6	40.4
GASIRIDA	32	38.6	86	2	2.2	62.5	1	1.1	32	6.8	2.2	22.6	11	6.7	55.6
GITANGA	31	33	90	2.2	2.3	68.3	1	2.9	58.2	12.9	18.9	30.8	11.3	12.5	35.3
GLP2	93	35.7	86	2.2	2.3	59.1	1	3.9	32.9	21.9	7.1	28.2	11.5	8	30.4
GLP585	75	22.2	90	2.1	2.2	63.5	1	1.1	31.7	26.4	6.9	24.7	14	7.2	60.6
Kanyebwa	67	32	86	2.1	2.2	61.4	1.1	1.9	36.4	26.9	14.4	25.7	12	8.3	55.1
KATB1	41	33.5	86	2.2	2.3	62.2	1	1.1	54.3	7.4	37.8	32.2	11.1	14.6	45.7
KATB9	80	36.8	86	2.1	2.2	58.4	1	1.1	27.5	20	4.7	27.1	11.9	9.9	49.4
KATSW-10	55	18.6	90	2	2.1	62.8	1.1	2.1	79.9	5.2	19.9	51.3	5.3	17.2	39.7
KATSW-12	57	19.1	90	2	2.2	60.4	1	2.8	80.5	4.8	21.2	51.7	5.2	17.4	45.6
KATSW-9	54	18.1	90	2	2.1	61.8	1	1.2	80.2	4.3	20.3	50.3	5.2	16.8	48.8
KK8	106	41.3	86	2	2.4	66.7	1	1.6	38.8	21.4	10.3	21.5	11.9	5.4	42.6
MAC 44	112	38.2	86	1.7	2.2	64	1.1	2.1	39.3	18	8.7	23.8	11	7.2	56.9
MAC 49	111	35.4	86	2.1	2.5	69	1	1	48.6	22.8	14.4	25.4	11.9	9.6	56.1
Maharage Soja	4	19.9	90	2.1	2.1	56.5	1	3.8	64.4	10.6	24.9	34.2	9.2	13.6	62.5
MASINDI YELLOW LONG	133	31.7	86	2.2	2.3	62.5	1	1.8	55.4	7.8	32.9	32.9	11.1	15	50.1

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MASINDI YELLOW SHORT	132	33.3	86	2.2	2.3	61.5	1	2.1	53.2	7	36	32.5	11.6	15.4	57.7
Mexico 142	50	16.4	90	2	2.1	63.2	1	1.6	89.5	4.9	22.1	48.4	4.6	15.9	33.7
MEXICO 54	66	33.9	90	1.7	2.3	69.6	2.1	2.1	48.9	22.3	16.5	23.8	8.3	5.1	29
Michelite	51	15.6	90	2	2.2	62.8	1	1	85.1	4.5	19.6	49.2	5.6	15.4	38.7
NABE11	18	43.1	86	2.1	2.4	64.5	1	1.9	56.9	19.4	30	26.8	12.2	11.4	51.9
NABE12C	27	38.6	86	2.2	2.4	67.6	1	1.1	48.5	14.1	17.2	26.4	11.3	9.8	46.3
NABE19	99	37.4	86	2	2.3	64.4	1.1	1	38.5	22.5	7.6	29	12.7	11.8	48.4
NABE2	44	19.1	93	2.1	2.2	67.4	1.8	2.8	34.2	0.9	1.5	19.9	6.2	2.7	40.6
NABE20	68	40.8	86	2.1	2.4	65.7	1	1.2	42.6	27.1	18	25.9	13.1	8.2	41.8
NABE21	26	31.2	86	2.2	2.4	64.2	1	2	53.4	17	25.4	24.9	11.2	9.7	49.1
NABE23	16	37.9	86	2	2.3	64.3	1.1	1	41.2	22.2	14.6	24.2	11.2	6.8	51
NABE26C	110	33.8	86	1.6	2.2	64.6	1.1	1.1	40.9	16.5	9.8	26.1	12	9.8	46.5
NABE29C	81	46.6	86	2.2	2.2	61.7	1	1.2	33.4	11.4	3.1	22.9	12.1	5.4	49
NABE6	58	19.9	90	2.1	2.1	59.9	1.1	3.1	72.8	5.3	20.6	49.3	4.3	14.9	35.8
NABE9C	40	37.9	86	2.2	2.4	68.3	3.1	2.1	56.4	9.5	19.2	29.9	8.6	9.8	27.1
NGWAKU NGWAKU	36	39.5	86	2.2	2.3	62	1	1	45.7	18.9	31.3	24	11.5	8.3	52.8
NGWIN X CAB 2	21	36.5	86	2.1	2.4	65.1	1	1	64.1	12.6	19.8	29.7	11.1	11.4	48.4
NUA 689	88	32.5	86	1.2	1.4	59.2	1.1	2.3	39.6	23.7	13.3	24.5	13	9.1	114.7

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NUA45	35	48.9	86	1.2	1.6	65.4	1	2.2	35.1	22.6	7.7	28.4	13.8	10.8	62.5
RANJONOMBY	128	26.8	86	2.2	2.4	66.7	1	2	100.3	2.5	20.1	49.3	5	17.5	40.3
RWV3006	130	38.7	86	1.5	1.8	66.9	1	2.8	84.8	3.5	16.5	45.7	6.1	17.4	36.1
RWV3316	131	38.5	86	1.4	1.9	63.6	2.1	2.3	80.9	3.1	14.7	49.1	5.8	17.8	34
SAB 622	85	36.9	86	1.8	2.2	62.9	1	1	34	27.8	8.3	28.1	12.7	11.3	57.4
SAB 630	23	33.9	86	2	2.3	67.1	1	1	55	16.6	22	25.3	10.6	9	33.1
SAB 659	114	43.8	86	1.9	2.2	63.4	1	1.1	38.9	26.7	13.9	26.6	12.6	10.1	49.4
SAB 686	25	36.9	86	2.1	2.3	66.2	1	1	57.1	16.9	23	28.6	12.7	12.5	37.5
SAB 712	129	35.1	86	1.9	2.2	60	1.1	2.1	82.1	3.9	20	49.3	4.4	16.8	46.3
SELIAN 97	83	24.9	86	2.1	2.4	63.6	1.1	1.1	38.3	22.4	5.7	27.7	11.6	10.7	63
TU	123	22.8	93	1.2	1.4	65.7	1	1.8	27.5	2.6	1.4	18.6	5.1	1.2	88.6
UBR (92)25	53	18.6	90	2	2.1	63.9	1	1.9	78.5	5.5	21.7	50	5	17	38.9
VAX4	122	21	93	1.1	1.6	67.6	2.1	1.3	30.7	1.4	-0.7	18.3	5.6	1.5	81.8
VAX5	28	20.5	90	2.1	2.3	63.1	1.1	1.9	56.3	15.9	19.5	28	11.5	10.4	62.8
VCB81013	64	25.5	90	2	2.1	65.3	1	1.8	82	3.1	16.5	48.4	5.7	16.3	43.4
VTTT 923/10-3	22	45	86	2.2	2.4	64.2	1.1	1.3	63.4	16.4	23	30.8	11.7	13.3	48.4
Mean		30.8	88	1.9	2.2	63.9	1.2	2	48.7	13.9	13.6	30.1	10.3	10.5	49.4
Minimum		14.4	86	1.1	1.4	55.5	1	1	25	0.4	-1.9	17.5	4.3	0.8	19.3

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AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 22 No. 8
October 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Maximum		63.7		93	2.2	2.5	69.6	3.8	4	100.3	27.8	39.9	52.2	15.3	18.6	114.7
AAC Cranford	135	63.7		86	2.1	2.3	66.4	2.2	3.3	63.4	13.6	18.7	33.4	13	14.1	23.7
LSD (0.05)		2.7	n/a		0.1	0.1	2.6	1.4	0.9	5.4	1.5	1.7	1.3	0.8	1	4.8
AAC Expedition	136	42.1		90	2.2	2.3	67.1	3.8	4	74.9	6.4	14.3	38.3	10.6	16	24.3
LSD (0.05)		2.9	n/a		0.1	0.1	2.7	1.5	1	5.7	1.6	1.8	1.3	0.8	1	5.1
AC Black Diamond	137	24.3		93	1.9	2.2	67	1.6	2.7	29.8	0.7	-1.9	23	7.7	5.3	36.5
LSD (0.05)		2.9	n/a		0.1	0.1	2.7	1.5	1	5.7	1.6	1.8	1.3	0.8	1	5.1

Three check lines were used, AAC Cranford (Main check, 12 replicates, large seeded); AAC Expedition (Secondary check, 5 replicates, medium seeded); and AC Black Diamond (Secondary check, 5 replicates, small seeded). HCS = hydration coefficient after soaking, HCB = hydration coefficient after blanching, SW100 (g) = weight of 100 dry bean seeds, LSD = least significant difference