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Research Article

Phenotypic Diversity of Cowpea (*Vigna unguiculata* L. Walp) Based on Shorter Cooking Time and Canning Quality Traits

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ABSTRACT

Cowpea is a leguminous crop rich in protein. Despite its nutritional quality, the crop is underutilized due to its prolonged cooking time requiring energy to make it palatable. This study investigated the adaptive capacity, cooking time and canning quality of a panel of 94 accessions of cowpea obtained from the International Institute of Tropical Agriculture IITA, Ibadan and Rumukoro Market Port Harcourt, Nigeria. Seeds were planted at the Department of Crop and Soil Science Research Farm and Allu Town, University of Port Harcourt, Nigeria. The experimental design was randomized complete block design (RCBD) in three replicates for three seasons (early wet, late wet and dry season). Agronomic parameters such as plant height, number of leaves, number of branches, leave length, leave width, flowering date and number of pods were collected at two weekly intervals after two weeks of planting. The cooking evaluation was carried out using a digital cooker (Tower Product), while canning quality was evaluated using a cost-effective sealer. Results obtained showed that cowpea adapted to the three seasons with optimal performance observed in the late wet season. The cooking results showed that TVU-2, TVU-8, TVU-9, TVU-13, TVU, 21, TVU29, TVU-36, TUV-38, iron white, akara bean, iron brown and honey bean had shorter cooking time (50-51mins.) while TVU-2, TVU-13, TVU-26, TVU-37, TVU-38, TVU-45, TVU-50 and TVU-51 had good canning quality. It was recommended that the selected accessions for better agronomic and culinary quality traits can be used for cowpea breeding programmes.

INTRODUCTION

The fast-growing world population and the obvious consequences of climate change have caused challenges leading to household food insecurity (Lobell et al., 2008). Legumes have been reported to be super-foods for their high nutritional (protein) component and resilience plants because of their high adaptive capacities to climate change.

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One such legumes that hold promise is cowpea (*Vigna unguiculata* (L.) Walp.). It is one of the main staple pulses commonly grown in most tropical areas across the globe, particularly in West Africa (Joseph et al., 2011, & Muranaka1 et al., 2016). It is a victual legume of the family Fabaceae (Afakwoa et al., 2006; & Appiah, 2011), commonly known as China pea, Southern pea, Cow gram or Black-eyed bean. The report shows that Africa is the centre of origin and is widely distributed in temperate and tropical regions. Variations exist amongst the seeds in shape, size, and coat colour (Ashogbon & Akintayo, 2013). Cowpea is one of the major essential pulses, with about 5.39 million metric tons of world production (FAO, 2010) and the most vital source of plant protein in the nutrition of people in Africa regions, especially Nigeria (Sefa-Dedeh et al., 2000, Afoakwa et al, 2002, Amonsou et al., 2010, Joseph et al., 2011, & Muranaka1 et al., 2016). Nigeria is the principal producer of cowpea, with the production of approximately 2.1 million tonnes yearly, accounting for production of about 61% in Africa and 58% across the globe (Tariku, 2018).

Despite the high nutritional value of cowpea, its utilization has been decreasing since the 1960s, mostly as a result of changes in consumers' choice and for cultural and social reasons (Pedrosa et al., 2014). According to a recent report by Odogwu et al. (2021), cowpea is underutilized in a good number of Nigerian homes and commercial eating-houses due to the long preparation and cooking time which requires moderate to high amount of energy to soften them to become palatable (Yeung, 2007). Cooking time is a major reason most consumers prefer to save time in food preparation (Silvia et al., 2017). There is a need for new preparation and processing methods to increase the nutrients' bioavailability and improve cowpea quality.

Therefore, recent studies have shown that there is gradual development and optimization of different preservation methods, thereby making cowpea readily available (Afoakwa et al., 2006 & Trust, 2012). Both traditional and modern food processing technologies also accelerate the use of cowpea by converting the raw seeds into various end products with desired quality such as "ready-to- eat". "Ready-to- eat "cooked beans accessibility increases the household consumption and modifying it to present-day way of life since the conventional approaches of preparation are usually laborious and consumes time. In most advance countries, cowpea is packaged, pre-cooked and canned. Even though traditional drying method are economical, canning of cowpea has been confirmed to effectively reduced the amount of energy necessary for cooking, heighten the retention of nutrients, increased the shelf life of the grains; reduced losses due to post-harvest storing and paved way for the global export markets (Cavalcante, et al., 2017, Amonsou et al., 2010; Sasikala et al., 2011 & Afoakwa, et al., 2013). In view of these, this research evaluated the diversity of a set of cowpea accessions for agronomic, cooking time and canning quality traits.

MATERIALS AND METHODS

This research was carried out at the Department of Crop and Soil Science research farm Faculty of Agriculture, and Department of Plant Science and Biotechnology, Faculty Science, University of Port Harcourt, Nigeria. A panel of 94 Vigna accessions were used for this study, 88 obtained from the IITA (International Institute of Tropical Agriculture) Ibadan, Nigeria and 6 accessions were obtained from Rumuokoro market Port Harcourt Rivers State, Nigeria. The accessions Coded TVU are the cultivated cowpea, TVNU are the wild accessions, and 6 are the market class varieties.

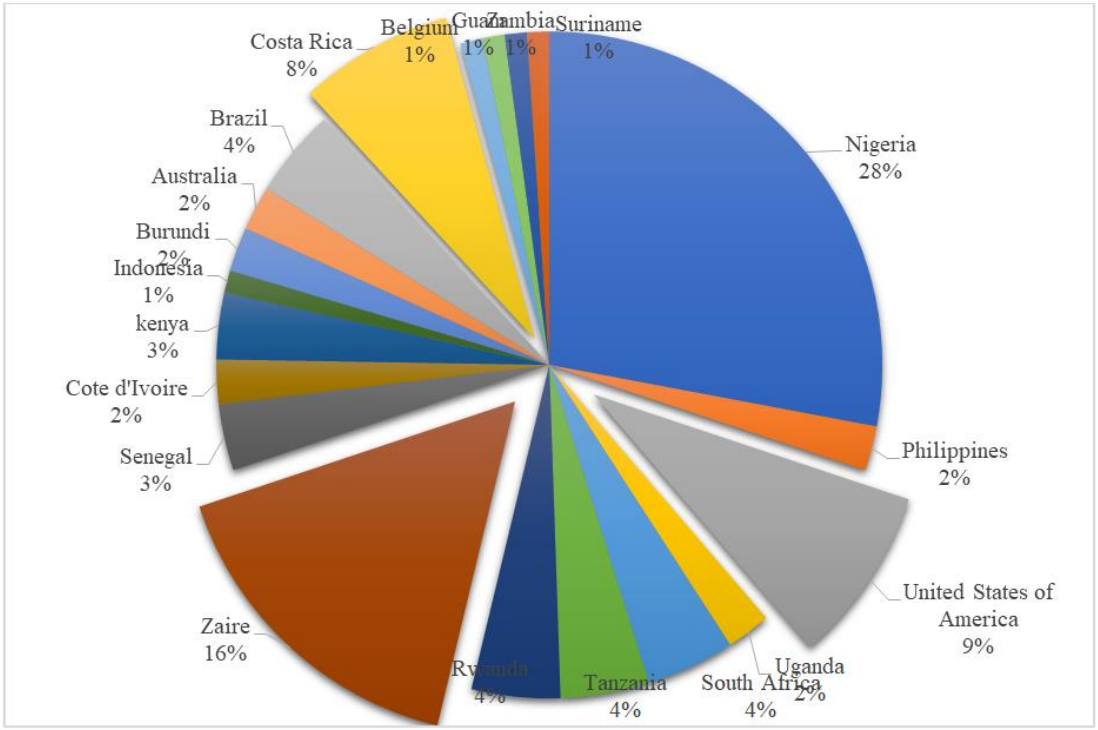


Figure 1: Diversity of the 94 cowpea accessions based on the country of collection

Growth Studies

Seeds were planted in ridges in 3 replicates in a randomized complete block with a spacing of 10m by 5m. Each accession of the 94 accessions were planted in two-row plots of 5 m using 0.20 m spacing within a row and 0.75 m between the rows. Planting was established under three seasons, viz. early wet, late wet and dry seasons. Agronomic parameters were obtained after two weeks of planting. These include, plant height, leave area (length and width), number of branches, number of leaves, flowering dates and number of pods per plant. Plants were watered regularly, and measurements were taken at two weeks intervals. Staking, weeding and pest control were carried out when necessary.

Cooking Time Evaluation

The initial weight of samples (25 seeds each) were recorded, and samples were then soaked at room temperature for 16 hours in 60ml of water in plastic Ziploc bags. The weight after soaking was also taken. The soaked samples were transferred in ziplock bags which were supported in boiling water using two rods in a digital multiple cookers (Tower Product). The increase in weight was used to calculate the cooking absorption (amount of water absorbed during cooking). Also, the broth containing cooked seeds were emptied into separate test tubes with caps while the samples were individually transferred into Petri dishes (Yeung, 2007). The following parameters were rated subjectively by trained evaluators in a scale of 1-5: seed color, seed aroma, tactile texture, cooked doneness, broth opacity, seed coat split and cracked cotyledon, according to Yeung, (2007).

Canning/ Sealing Methodology

This was a modified cost-effective alternative method for canning of cowpea. 25 seeds for each accession were weighed and soaked with 60mls of distilled water for 16 hours (Naju, 2016). The soaked seeds were weighed after soaking. Seeds were blanched for 15 minutes in water of 90° C, drained, weighed, and then transferred to sachets. 10mls of Brine solution (Sodium hexametaphosphate) was added and sealed with an automatic nylon sealer. The sealed sachets were sterilized in a pressure cooker at 125° C for 60 minutes, followed by instant cooling. After seven days, the sealed beans were opened using scissors. Canning quality attributes were determined using the following parameters:

(i) Hydration coefficient (HC)

(ii) Washed drained weight (WDWT) and percentage washed drained weight (PW) DWT), pH measurement, the seed size and seed shape, uniformity, splits, degree of clumping, brine clarity, and sensory evaluation using a 7-point scale (Loggerenberg, 2004).

Leached solids

The soluble solid lost was determined using °Brix refractometer according to Yeung et al. (2007). The final broth weight was estimated.

Data Analysis

Statistical analysis for ANOVA and correlation for the agronomic parameters and Likert scale for cooking time and canning quality were conducted using SPPS Version 2016.

RESULTS AND DISCUSSION

Growth Studies For Three Seasons

Table 1. Mean and standard error of the agronomic parameters of the accessions evaluated

S/N	Season	Plant_ height	Leaf_ length	Leaf _ Width	Number of Leaves	Number of Branches	Flowering date	Number of pods
1.	Dry season	15.532 ±1.0213	10.632±0.4516	4.527±0.2014	7.377±0.3386	1.5±0.0896	32.94±2.085	1.4±0.222
2.	Early wet season	18.066±1.4354	4.255±0.3348	2.779±0.2239	9.712±0.702	2.5922±0.18739	6.09±1.323	0.22±0.054
3.	Late wet season	40.648±2.1757	18.289±1.002	6.5022±0.4742	24.1824±1.7637	2.7801±0.15458	45.08±1.721	1.92±0.166

Table 2: Correlation table of agronomic parameters

	Plant_ Height	Leaf -Length	Leaf_ Width	Number of leaves	Number of Branches	Flowering Date	Number of Pods
Plant_Height							
Leaf_ Length	.670**						
Leaf _Width	.710**	.849**					
Leaf_ Number	.785**	.723**	.747**				
Number of Branches	.656**	.509**	.565**	.701**			
Flowering Date	.355**	.565**	.536**	.334**	.201**		
Number of Pod	.400**	.529**	.472**	.445**	.316**	.479**	

The correlation coefficients among the parameters studied showed positive correlation at (0.005) viz plant height, leaf length, leaf width, number of leaves, number of branches, flowering date and number of pods measured.

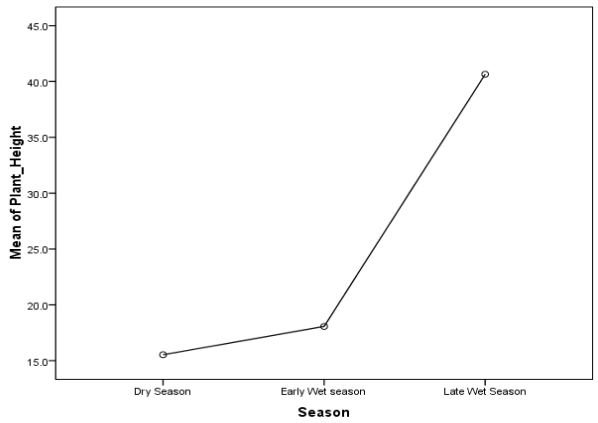


Figure 1a

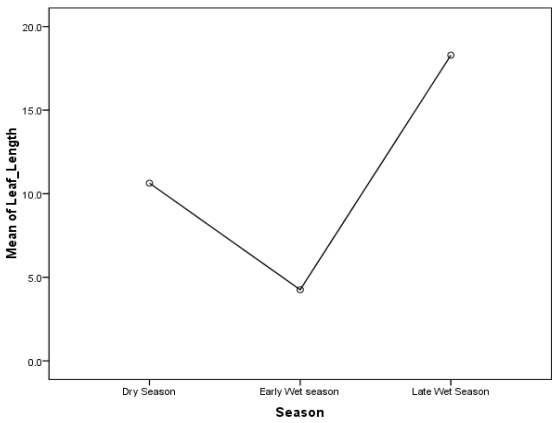
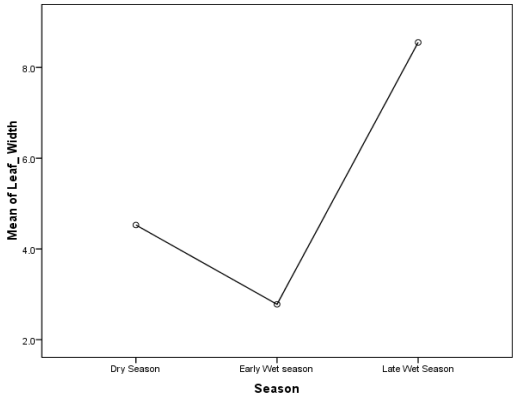


Figure 1b



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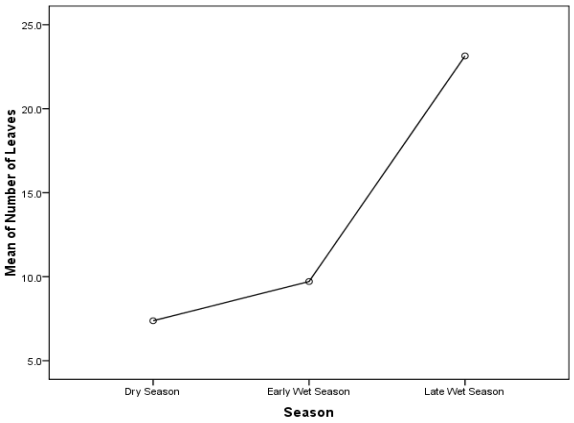
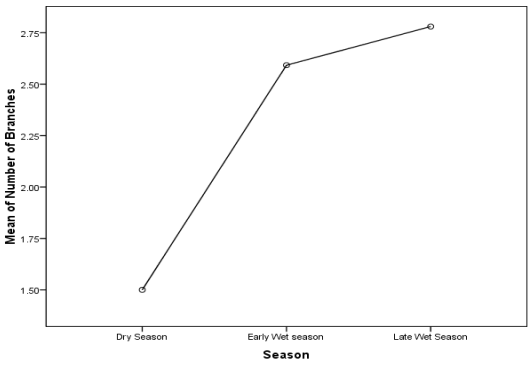


Figure 1d



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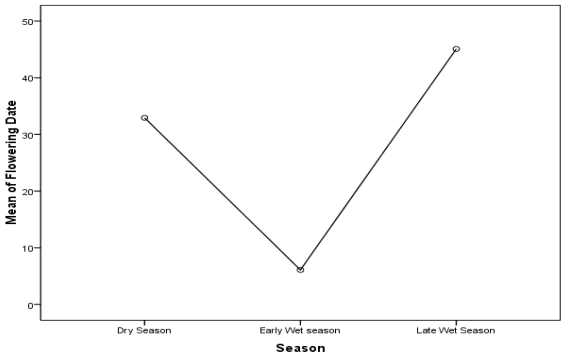

Figure 1f

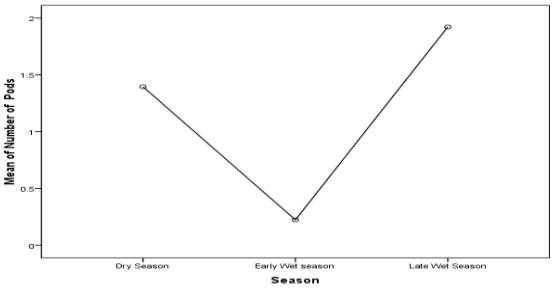

Figure 1g

Figure 1 a, b, c, d, e, f and g: Mean plots for the agronomic parameters for the three seasons

Planting was carried out in three different seasons viz early wet, late wet and dry seasons in Port Harcourt, South-South of Nigeria in other to assess the adaptive capacity of the cowpea accessions. The result showed that they generally adapted to these three seasons. The mean and standard error for the agronomic parameters assessed showed that the optimal performance was in the late wet season while the lowest performance was in the early wet season except in plant height where the dry season was the lowest (15.532 ±1.0213) as shown in Table 1. This can be confirmed in the mean plot of all the agronomic parameters studied in figure 1 a-g. The correlation coefficients among the parameters studied showed positive correlation at (0.005) for plant height, leaf area (leaf length and, leaf width), number of leaves, number of branches, flowering date and number of pods measured as shown in table 2 above. Their optimum performance was noticed in the late wet season suggesting that weather is a major factor in cowpea

production. There were observable variations in the average growth rate in the different seasons. The environmental condition in the late wet season could be very favourable due to the moisture content and genetic difference among the genotypes. The excessive moisture in the wet season and low moisture in the dry season could have negatively affected the optimal performance of the plant (Tettey et al., 2018).

Early maturity is one of the important agronomic trait in adaptation studies of annual crop to agroecological zones. Agronomic parameters can be applied together with morphological traits to select desirable characteristics. Morphological and agronomic characters were used for the identification of desirable traits such as seed coat colour, plant morphology and pod characteristics in cowpea (Doumbia et al., 2013). Agro morphological classification in these cowpea accessions would provide genetic information. Even though environmental factors significantly influence the morphological variation, morphological traits can still be precise and efficient for selection and is the pre-requisite for breeding programmes.

Table 3: Cooking time evaluation of cultivated accessions of cowpea

Accession	Solid loss (%)	Seed Color	Seed Aroma	Tactile Texture	Cooked Doneness	Broth Opacity	Seed Coat Split	Cracked Cotyledon	Cooking Time
TVU-1	10.9	1.6	2.4	2.4	3.0	2.8	2.0	0.0	77
TVU-2	12.0	4.2	2.0	2.4	2.6	2.6	1.8	6.6	50
TVU-4	6.5	4.0	2.2	2.4	2.6	3.2	5.8	8.4	82
TVU-7	8.4	3.8	3.6	2.4	2.2	2.6	3.0	3.4	80
TVU-8	13.2	2.6	3.0	1.4	1.8	2.8	2.0	0.6	50
TVU-9	11.2	2.8	3.4	2.8	2.2	3.0	2.2	2.0	50
TVU-11	7.6	2.6	2.2	3.6	1.8	3.8	1.0	2.0	77
TVU-12	6.1	4.4	2.4	2.8	3.2	3.8	5.0	7.8	63
TVU-13	11.2	2.6	2.8	2.6	2.6	2.6	7.2	1.8	50
TVU-16	5.5	2.6	2.2	1.8	2.6	1.8	0.4	0.4	60
TVU-18	10.0	1.2	1.4	1.8	1.6	3.0	0.6	0.4	63
TVU-19	4.0	3.8	2.6	2.2	2.0	3.2	2.8	4.6	60
TVU-20	7.0	3.4	3.4	3.0	2.6	3.0	3.2	4.6	90
TVU 21	8.9	2.4	3.4	3.0	2.8	4.0	3.6	3.4	50
TVU-22	5.4	2.4	2.6	3.8	1.6	2.2	0.4	1.4	67
TVU-23	5.1	4.0	2.4	2.2	2.0	3.0	4.8	3.6	90
TVU-24	5.6	3.6	1.8	1.4	1.4	3.0	9.4	5.4	67
TVU-25	6.8	4.0	2.4	2.2	3.2	3.6	7.6	5.6	64
TVU-26	6.7	2.4	2.2	3.4	1.6	1.4	1.2	3.8	82
TVU-27	6.6	4.8	3.8	3.2	4.6	1.8	7.8	3.4	82
TVU-28	7.9	3.6	2.2	2.2	3.2	3.6	2.4	5.2	80
TVU-29	5.1	1.6	2.0	1.6	2.8	2.8	0.6	1.2	50
TVU-30	9.3	2.6	2.4	2.2	3.8	4.2	0.4	2.6	77
TVU-31	9.5	3.0	3.0	1.6	1.8	3.8	4.0	6.8	95
TVU-32	13.3	3.0	2.0	2.2	2.6	4.4	5.4	2.0	77
TVU-33	11.3	3.0	3.6	4.0	2.8	3.2	4.0	4.8	82
TVU-34	7.0	2.2	2.0	2.6	2.6	2.4	7.8	2.0	95
TVU-36	9.3	2.6	2.0	2.8	3.2	2.4	0.8	0.6	50
TVU-37	11.0	2.6	2.0	2.8	2.8	3.0	0.8	1.4	95

TVU-38	13.7	2.4	2.0	3.6	4.2	3.5	12.2	3.2	50
TVU- 39	11.0	2.8	1.8	3.2	3.6	3.6	2.6	1.8	78
TVU-40	10.8	2.0	3.0	2.6	3.0	3.6	1.8	2.0	78
TVU-41	8.2	1.6	2.6	3.0	3.0	4.0	2.0	1.6	92
TVU- 42	12.8	2.4	2.6	3.0	2.8	3.0	0.4	1.0	78
TVU -43	13.0	2.2	2.6	2.6	2.8	3.2	2.2	1.4	78
TVU- 44	10.6	2.4	2.8	2.6	2.8	4.0	0.4	0.6	60
TVU-45	11.5	2.2	2.8	2.8	2.8	4.0	0.8	0.4	92
TVU-49	13.8	1.8	2.6	1.8	2.4	3.2	1.8	0.8	78
TVU-50	13.7	3.4	4.0	1.6	3.6	3.2	2.0	1.2	50
TVU-51	13.4	3.6	3.0	2.4	3.0	3.0	2.0	1.0	78
TVU-52	13.8	2.4	2.4	2.4	2.6	3.0	1.8	2.2	92
TVU-53	8.7	3.8	4.0	2.4	3.0	3.4	2.4	3.0	80
TVU-88	6.0	3.4	2.8	1.8	2.2	3.0	11.6	0.4	92
TVU-17	4.7	4.0	3.8	2.4	2.0	2.0	0.8	11.4	92
TVU-91	12.5	2.6	2.2	2.2	2.4	3.2	4.6	2.4	78
TVU-14	6.9	2.2	2.8	2.4	2.0	3.6	9.4	12.8	78
TVU-140	10.0	1.2	1.4	1.8	1.6	3.0	0.6	0.4	78
TVU-73	4.0	3.8	2.6	2.2	2.0	3.2	2.8	4.6	78
TVU-77	7.0	3.4	3.4	3.0	2.6	3.0	3.2	4.6	78

Table 4: Cooking time evaluation of wild accessions of cowpea

Accession	Solid loss (%)	Seed Color	Seed Aroma	Tactile Texture	Cooked Doneness	Broth Opacity	Seed Coat Split	Cracked Cotyledon	Cooking Time
TVNU-3	8.9	2.4	3.4	3.0	2.8	4.0	3.6	3.4	193
TVNU-11	10.8	2.4	4.4	1.6	2.0	4.6	2.4	1.0	133
TVNU-16	9.4	2.4	2.6	1.6	2.8	2.6	4.6	9.8	133
TVNU-19	9.9	2.6	2.6	2.6	2.4	2.2	2.6	1.0	193
TVNU-20	11.1	2.6	2.0	2.0	2.6	2.2	1.2	0.8	193
TVNU-24	10.6	3.0	2.4	2.0	1.8	2.0	3.8	2.2	133
TVNU-26	12.7	3.0	2.4	2.0	2.0	2.0	3.0	1.4	193
TVNU-28	10.6	2.4	2.2	2.0	1.8	2.0	1.8	0.8	193
TVNU-35	12.2	2.6	2.4	1.4	1.2	1.8	9.0	2.4	133
TVNU-39	13.0	2.2	2.2	2.8	2.8	1.8	4.0	1.2	133
TVNU-40	13.9	2.2	2.4	2.4	2.8	1.8	3.8	0.2	133
TVNU -41	13.8	2.0	2.2	2.2	3.0	2.2	2.8	0.6	133
TVNU-42	11.5	2.0	2.6	2.2	2.2	2.6	0.6	1.4	133
TVNU-44	14.0	2.2	2.0	1.4	2.0	3.0	0.2	1.2	193
TVNU 46	13.7	1.4	2.4	1.2	1.8	4.4	2.8	0.8	193
TVNU-47	8.6	2.8	3.0	3.0	2.6	2.0	1.8	0.6	193
TVNU-49	10.4	3.0	2.4	2.4	3.6	2.2	0.4	1.2	115
TVNU-50	7.3	2.2	2.4	2.2	3.4	1.4	11.0	8.0	92
TVNU-53	10.5	2.8	3.2	2.2	2.8	4.0	4.6	5.2	193
TVNU-54	11.6	2.6	2.8	2.6	2.8	4.2	6.2	4.6	133
TVNU-56	7.5	2.6	2.2	1.8	2.4	4.4	5.0	4.6	133

TVNU-57	14.0	2.8	1.8	1.2	1.6	1.4	8.0	4.8	92
TVNU-59	13.6	2.0	2.4	2.2	1.8	1.2	9.4	6.0	193
TVNU-64	7.8	1.8	2.2	2.6	2.6	3.2	1.2	0.2	133
TVNU-66	12.5	1.2	2.2	1.6	1.6	1.2	0.6	1.0	193
TVNU-67	13.6	3.8	2.2	1.6	2.6	3.2	2.6	2.8	193
TVNU-69	14.0	2.0	2.0	1.4	1.2	1.6	0.2	0.0	193
TVNU-70	12.8	2.6	1.8	1.8	1.6	3.6	10.4	5.8	133
TVNU-71	9.2	2.8	2.4	2.0	2.4	2.2	13.8	6.0	193
TVNU-72	13.6	2.6	3.6	2.6	3.2	3.2	1.0	2.6	193
TVNU-73	13.3	2.8	3.6	1.4	1.6	2.2	4.0	3.6	193
TVNU-74	13.1	2.8	2.6	2.2	2.4	2.0	11.0	5.0	193
TVNU-10	12.7	2.8	2.8	3.4	2.6	1.4	4.4	1.4	103
TVNU-141	10.6	2.8	2.4	2.0	2.4	2.0	1.8	1.2	193
TVNU-89	10.3	2.4	2.2	1.8	1.8	1.4	3.8	2.3	193
TVNU-84	13.7	3.0	2.4	2.0	2.0	2.0	3.0	1.4	78
TVNU-86	11.3	2.0	3.0	2.4	2.2	2.2	2.2	1.6	95
TVNU--35	14.0	2.8	2.8	3.4	3.4	2.0	2.0	1.4	95
TVNU-2	10.7	2.2	2.4	1.2	1.0	1.6	0.2	0.0	180

Table 5: Cooking time evaluation of market class varieties of cowpea

Accession	Solid loss (%)	Seed Color	Seed Aroma	Tactile Texture	Cooked Doneness	Broth Opacity	Seed Coat Split	Cracked Cotyledon	Cooking Time
ALOKA	6.5	4.0	3.0	2.0	2.2	3.8	5.2	4.4	77
PATASCO	5.0	4.2	3.0	2.4	1.6	3.0	6.6	6.2	90
HONEY_BEAN	3.1	4.2	3.4	2.8	3.2	2.6	4.8	8.0	51
AKARA_BEAN	5.3	4.4	3.2	2.6	2.2	2.8	6.0	9.6	51
IRON_WHITE	5.0	5.0.	2.6	2.6	2.4	4.0	15.2	10.4	50
IRON_BROWN	6.3	3.2	2.2	2.0	2.4	2.6	8.0	6.0	50

Cooking time evaluation

Cooking quality of cowpea was determined by subjectively assessing cooking time, aroma of seed, tactile texture, cooked doneness, seed colour, broth opacity, seed coat and cotyledon splitting, and solid loss rated on a 1-5 scale. The result showed that soluble solid loss was on the scale of 3.1-14%. Solid loss has a direct relationship with broth opacity implying that seeds with blurry broth would have a high amount of solid loss. The market class varieties possessed high amount of solid loss and blurry broth. Seed color were between white, milk, brown and black for all the accessions.

Shivachi et al. (2012) noted that cream or white colored pulses are preferable because the dark-coloured ones have high antinutrients, leading to a bitter taste. This is in line with this study in that the wild accessions (TVNUs) are very dark in colour. Negri et al. (2001), however revealed that some consumers prefer dark-coloured seed while others prefer white seed because their colors are not changed when cooked. The taste of the beans may be different irrespective of the color (Ngure, 2021). Based on tactile texture, seeds of some of the TVU genotypes were unable to smash, some were hard (mainly the TVNUs and others firm smashes easily (TVUs and Market class varieties). Tactile texture was observed on the scale 1.8- 3.0 difficult to smash and firm but smashes easily for the TVUs, for the TVNUs, seeds were generally hard apart from TVNU-3, TVNU-47 and TVNU-35. For the market class varieties, seeds were less difficult

to smash and cotyledon slightly hard (2.4-2.8). Cooked doneness were from under cooked (most TVNUs), cooked (Most TVUs) and slightly overcooked (some Market class). These differences could be as a result of thickness and the texture of the seed coat, the firm attachment of the seed coat to the cotyledon, hilum and micropyle and size of the overall seed (Olapade et al., 2002, & Wang et al., 2003). Bigger seeds cooked faster than the smaller seed indicating that size is a factor affecting cooking time. This is in line with the results of Demooy and Demooy (1990) and Olapade et al. (2002) however, Yeung, (2007) discovered that size does not affect cooking time. Based on colour and broth opacity of seed, the smaller seeds had clear broth while the bigger seeds with darker colour had opaque broth. The seed aroma ranged between 2.0-4.0, which is faint and apparent, while TVU-18, TVU-24, TVU-29, TVU-31, TVU-39, TVU-50, TVU-140 had faint aroma. The seed aroma for the TVNUs were all faint except TVNU-3 which is apparent and TVNU-11 is more apparent TVNU-57, TVNU-70 which have nearly none aroma. And all the market class genotypes except iron white and brown beans possessed faint aroma on the scale of 2.6 and 2.0. Another important quality trait of beans is seed splitting and cotyledon breakage. TVU-38 and TVU-88 had up to half of the seeds split and TVU-17 with a cotyledon break. TVNU-11 and TVNU-50 had the highest cracked cotyledon while TVNU-2 had no cracked seed unlike the market class with more cracked seeds; cooked doneness observed were on the scale 1.6-3.0, undercooked-slightly to overcooked. Text was blurry for the market class variety. Most of the TVUs (cultivated accessions) possessed shorter cooking time with TVU-2, TVU-8, TVU-9, TVU-13, TVU, 21, TVU-29, TVU-36, TUV-38 having cooking time of 50 minutes. and iron white, akara bean, iron brown and honey bean (Market-class) having the cooking time of 51 minutes. The fast-cooking time was probably as a result of quick penetration of the seed coat and cotyledon of these genotypes to the water used in cooking and followed by rapid softening of the seed; it is also probable that bigger starch granules gelatinize faster than smaller ones (such as in TVNus) (Adebooye, 2007). Wiesinger, et al. (2016) noted that storage conditions and planting environment can affect the cooking time of cowpea seeds. This result indicate that TVU-2, TVU-8, TVU-9, TVU-13, TVU, 21, TVU-29, TVU-36, TUV-38 and iron white, akara bean, iron brown and honey bean would be preferred by consumers as they were the accessions identified with shorter cooking time. Studies show that the cooking time of cowpea seeds are between 35 – 120 min or more, based on the genotype involved and the cooking process applied (Olapade et al., 2002, & Obasi, et al., 2014). Other studies recorded 57mins. for Nhyira, 65 mins. for Tona and 84 mins. for Adom genotypes, respectively (Appiah et al., 2011, & Hamid et al., 2016). Shorter cooking time is required as it lowers the energy used in cooking and is also cost-effective (Owusu et al., 2018). The cooking time of the TVNUs were undesirable as they had longer cooked time, with highest ranging 133-193 minutes, such as TVNUs 47, 49, 50 53,56, 59, 61,73, 74 and 75. Long cooking time is a major factor limiting the utilization of cowpea in that a reasonable amount of energy is needed to make the grains palatable. Cowpea consumers in Africa are, however willing to pay premium price for important (desired) culinary quality traits (Langyintuo et al., 2004). Decreasing the cooking time is a vital component of cowpea which would be important, particularly in regions where cowpea is consumed primarily as a source of protein. Limited information exists as to the cooking time of the TVNUs however, their longer cooking could be attributed to the hard seed coat and smaller seeds. They can, however, be incorporated into breeding programmes for improvement.

Table 6: Canning quality evaluation for cultivated accessions of cowpea

Accession	Solid loss (%)	PH	Seed Size	Seed Shape	Uniformity	Seed Split	Degree of Clumping	Brine Clarity	Sensory Evaluation
TVU-1	9.5	5.9	4.3	3.0	1.7	4.5	5.3	5.5	5.0
TVU-2	12.3	6.0	4.0	3.0	1.5	6.2	5.7	5.0	5.7
TVU-4	7.0	5.7	4.8	4.5	1.5	5.3	6.5	6.2	5.7
TVU-7	7.0	5.9	4.7	4.0	1.3	6.3	4.8	6.0	5.0
TVU-8	8.9	5.8	3.2	3.3	1.7	6.3	6.2	6.3	6.3
TVU-9	8.2	5.8	3.3	4.5	1.3	5.2	7.0	5.7	6.7
TVU-11	5.9	5.6	4.2	3.7	1.5	4.8	4.5	4.7	5.2
TVU-12	5.7	5.9	4.7	4.5	1.5	5.3	4.3	4.8	6.5
TVU-13	8.1	5.8	2.7	3.8	1.2	6.0	5.7	6.0	6.0
TVU-16	2.9	5.8	4.5	4.8	1.3	6.2	5.7	6.2	5.7
TVU-18	8.5	5.9	4.8	5.7	1.3	5.5	6.3	2.5	5.2
TVU-19	8.5	5.5	4.8	6.0	1.3	6.0	7.0	2.5	5.2
TVU-20	7.4	5.8	4.8	5.8	1.7	3.0	4.3	3.7	3.0
TVU 21	7.4	5.8	5.0	4.3	1.3	3.3	4.7	5.0	3.0
TVU-22	6.3	5.7	5.2	2.2	1.3	3.2	5.7	5.0	1.3
TVU-23	8.5	5.8	4.2	5.2	1.7	4.8	5.5	4.7	5.3
TVU-24	13.0	5.9	5.8	4.5	1.7	4.3	5.0	6.0	5.3
TVU-25	8.6	5.8	5.2	5.2	1.2	6.8	4.5	6.2	7.0
TVU-26	5.9	5.9	6.0	6.8	1.2	7.0	6.5	6.3	6.0
TVU-27	5.9	5.9	5.7	6.0	1.3	2.0	4.3	6.2	3.0
TVU-28	8.6	5.7	4.7	6.2	1.3	5.3	6.3	5.0	5.2
TVU-29	6.7	5.7	5.0	6.2	1.2	5.3	5.7	4.8	5.2
TVU-30	9.7	5.9	3.2	4.2	1.5	6.3	5.8	2.2	5.0
TVU-31	6.9	5.8	5.2	4.8	1.5	3.7	5.3	2.7	4.3
TVU-32	8.1	5.8	3.0	4.8	1.5	6.0	5.5	2.8	6.2
TVU-33	8.1	5.8	2.5	3.2	1.3	3.2	3.7	4.7	2.5
TVU-34	14.0	5.9	3.2	5.0	1.3	6.8	4.5	4.2	5.0
TVU-36	11.0	5.9	2.7	4.2	1.5	6.8	4.5	3.2	4.8
TVU-37	12.7	5.8	3.0	5.0	1.5	7.0	6.0	5.0	5.0
TVU-38	11.6	5.6	2.5	2.3	1.5	6.2	5.2	5.5	6.5
TVU- 39	12.6	5.8	3.0	5.0	1.5	6.0	5.0	6.0	7.0
TVU-40	6.5	5.9	3.0	4.8	1.3	6.5	4.3	4.3	5.8
TVU-41	7.1	5.8	1.2	3.7	1.5	2.8	2.8	5.2	4.5
TVU- 42	14.0	5.7	3.7	5.0	1.5	5.7	6.5	5.0	4.2
TVU -43	14.0	5.0	3.3	5.7	1.5	6.8	4.5	2.0	4.5
TVU- 44	14.0	4.8	3.0	6.0	1.2	6.8	6.0	5.0	5.0
TVU-45	3.6	5.6	4.0	5.0	1.3	6.0	7.0	5.8	5.3
TVU-49	10.6	5.9	2.7	3.7	1.3	5.3	5.5	5.2	6.0
TVU-50	8.2	5.8	3.2	5.3	1.2	6.3	4.3	6.3	7.0
TVU-51	8.0	5.8	3.3	2.5	1.5	7.0	4.5	7.0	6.8
TVU-52	5.6	5.8	4.7	5.0	1.7	6.3	5.8	6.3	4.5
TVU-53	12.8	5.9	5.0	2.0	1.7	3.5	6.3	7.0	3.7
TVU-88	7.8	5.9	3.0	3.3	1.3	3.2	4.8	3.0	5.8

TVU-17	6.5	5.7	4.7	4.5	1.3	4.5	5.0	4.5	6.8
TVU-91	7.8	5.8	3.2	3.0	1.5	3.5	5.8	5.0	4.2
TVU-14	14.0	5.8	5.2	4.3	1.5	2.8	3.2	4.0	3.5
TVU-140	8.5	5.9	4.8	5.7	1.3	5.5	6.3	2.5	5.2
TVU-73	8.5	5.5	4.8	6.0	1.3	6.0	7.0	2.5	5.2
TVU-77	7.4	5.8	4.8	5.8	1.7	3.0	4.3	3.7	3.0

Table 7: Canning quality evaluation for wild accessions of cowpea

Accession	Solid loss (%)	pH	Seed Size	Seed Shape	Uniformity	Seed Split	Degree of Clumping	Brine Clarity	Sensory Evaluation
TVNU-3	9.3	5.9	1.8	3.7	1.5	5.7	3.5	4.7	4.3
TVNU-11	13.3	5.8	1.0	3.8	1.7	6.8	5.2	4.5	3.7
TVNU-16	12.4	5.7	1.8	4.3	1.5	5.8	4.5	4.8	5.0
TVNU-19	12.8	5.8	1.5	3.7	1.7	6.7	6.5	5.0	5.0
TVNU-20	13.3	5.9	1.0	3.8	1.2	6.8	4.5	4.7	4.7
TVNU-24	5.3	5.7	1.3	3.8	1.2	6.3	4.5	2.7	4.7
TVNU-26	12.3	5.9	1.3	3.7	1.2	6.0	4.2	4.7	6.0
TVNU-28	13.8	5.9	1.0	4.0	1.2	6.5	3.8	4.7	5.7
TVNU-35	13.9	5.7	1.7	2.8	1.3	4.3	6.0	5.3	6.0
TVNU-39	14.0	5.9	1.0	3.8	1.5	7.0	4.2	6.0	5.0
TVNU-40	11.3	5.9	1.0	3.8	1.3	6.3	5.0	5.3	5.2
TVNU-41	12.3	5.9	1.0	3.8	1.3	5.5	3.5	4.7	5.0
TVNU-42	12.0	5.8	1.0	3.7	1.0	6.3	4.7	4.5	4.5
TVNU-44	9.3	5.9	1.0	3.8	1.2	7.0	4.0	6.2	4.2
TVNU 46	7.5	5.9	1.0	3.8	1.2	6.2	4.8	4.2	3.5
TVNU-47	11.0	5.8	1.0	4.0	1.2	7.0	5.0	6.0	3.0
TVNU-49	12.4	5.9	1.2	3.5	1.0	5.8	4.5	3.8	2.5
TVNU-50	10.4	5.9	1.3	2.7	1.7	6.3	4.0	5.2	4.3
TVNU-53	13.1	5.9	1.2	3.7	1.5	6.3	4.5	6.7	5.5
TVNU-54	14.1	5.6	1.3	3.8	1.7	5.3	4.8	4.2	4.4
TVNU-56	13.4	5.8	1.0	3.3	1.7	4.5	5.0	5.3	5.5
TVNU-57	11.2	5.9	1.0	4.0	1.2	7.0	7.0	7.0	6.0
TVNU-59	11.2	6.0	1.0	3.7	1.5	6.3	6.5	5.0	6.0
TVNU-64	8.3	5.8	2.0	4.3	1.7	6.7	5.5	6.2	5.8
TVNU-66	8.9	5.9	1.2	3.7	1.3	6.8	5.8	5.0	4.7
TVNU-67	9.7	5.8	1.8	3.7	1.3	6.8	5.8	3.3	4.8
TVNU-69	12.6	5.8	1.0	4.2	1.2	6.7	6.3	5.0	5.2
TVNU-70	7.4	5.9	1.7	3.8	1.2	6.3	5.2	4.8	5.3
TVNU-71	8.3	5.9	1.3	3.3	1.3	6.8	5.8	4.7	4.8
TVNU-72	9.2	5.9	1.7	5.3	1.7	5.7	5.8	4.7	4.3
TVNU-73	7.5	5.8	1.8	3.7	1.5	6.7	5.8	5.5	6.2
TVNU-74	3.9	6.0	1.0	3.7	1.3	5.7	5.5	3.0	3.5
TVNU-10	13.0	5.8	1.0	4.0	1.5	7.0	5.0	5.0	5.0
TVNU-141	14.0	5.9	1.0	2.2	1.5	6.2	4.3	6.8	6.5
TVNU-89	12.3	6.0	1.0	4.0	1.7	6.3	5.8	6.0	3.8
TVNU-84	11.4	5.8	1.3	4.3	1.3	7.0	4.2	5.0	3.8
TVNU-86	11.4	5.7	1.2	3.8	1.3	6.8	4.2	4.8	5.7
TVNU--35	14.0	5.9	1.2	3.7	1.3	5.8	4.3	5.7	5.5
TVNU-2	11.1	5.9	1.2	4.0	1.3	6.0	4.5	6.2	4.0

Table 8: Canning quality evaluation for market class varieties of cowpea

Accession	Solid loss (%)	PH	Seed Size	Seed Shape	Uniformity	Seed Split	Degree of Clumping	Brine Clarity	Sensory Evaluation
ALOKA	10.9	5.4	5.5	4.7	1.8	5.2	5.3	4.8	5.5
PATASCO	6.5	5.9	7.0	6.0	1.0	6.8	6.0	5.2	6.0
HONEY_BEAN	7.0	5.9	6.3	6.7	1.5	6.5	6.5	4.5	5.5
AKARA_BEAN	5.8	5.9	6.5	6.5	1.7	6.5	6.7	6.5	6.3
IRON_WHITE	5.8	6.0	5.5	7.3	1.5	6.8	6.7	6.0	6.5
IRON_BROWN	4.0	6.0	5.0	5.3	1.5	5.3	5.8	6.5	7.0

Canning quality Assessment

Canning evaluation was carried out using a cost-effective method in other to identify promising lines with good canning quality traits. Processing cowpea into canning and precooked products adds extra value to this grain legume (Siddiq & Uebersax, 2013). Canned beans are alternatives in food market as they are more convenient and readily available to grab (Zanovec et al., 2011) compared to dry beans, as they require much time in cooking (Bassinello, 2008). According to (Afoakwa et al., 2006 & Taiwo et al., 2009), parboiling and canning of legumes are more economical and it lowers energy usage and resources, prolongs the shelf life; lowers post-harvest losses due to storage and provides the opportunity for the exportation of the goods. Commercially hygienic mashed jollof beans from intact cowpea seeds in tomato sauce were brought to the market in Nigeria as a substitute for the already made baked beans. The product, regrettably, was not accepted by consumers, it was later removed from the market because the grains had splitting and a thick sauce of tomato of inadequate volume (Taiwo et al., 1997).

One feature that makes cowpea unacceptable for canning is the leaching of solid, known as solid loss. The market class varieties (aloka, honey bean, akara bean, iron white, iron brown and patasco) possessed high amount of solid loss. The solid loss for these accessions were 10.9, for aloka, 6.5 for patasco, 5.8 for iron white and 4.0 for iron brown. Results from this finding showed that smaller seeds or the wild class accessions did not leach, which could be due to their hard seed coat, consumers however, prefer bigger seeds without leaching ability. Hence the wild class can be crossed in breeding programs to improve the market classed varieties. The pH of the accessions ranged from 5.8-6.0. Njoro Canning confirmed that the standard pH is 5.2-5.9. Size and shape of canned beans are major quality parameters required by the canning industry as a result of consumers' preferred choice. Cowpea used for canning purposes should be even in size with consistent shape. For the seed size, most TVUs were between the scale of 3.0-6.0 which are slightly small to moderately large seeds except TVUs 22, 38 and 53 which are moderately small seeds. All the TVNU genotypes were small seeds. The market class were generally slightly large to large seeds. Seeds shape were 3.0-6.0 slightly elongated to moderately round except TVUs 22, 38, 51 and 53. TVNU seed shapes were between 2.0-4.0, moderately elongated to neither round nor elongated. The market class variety seeds were neither round to very round (4.0- 7.0). All seeds were very uniform ranging from 1.0-1.8. Uniformity in size, shape and color are considered among important canning quality attributes (Loggerenberg, 2004). Based on split, seeds were 4.0-6.0 from neither intact no broken to moderately intact for the TVUs. The TVNU seeds were 4.0-6.0, neither intact no broken to moderately intact seeds. Intact seeds were also identified for the market class variety. Studies by Warsame, (2013), showed that the lowest splits were on small navy and large red kidney bean genotypes having the highest split followed by PWDWT among small and large seed genotypes. On the contrary, Loggerenberg, (2004), discovered that bigger grains had fewer splits. Beans with fewer

splitting are preferable in canned beans (Taiwo, 1998). Soaking of cowpea was found to reduce the splitting (Taiwo et al., 1997). Based on size, bigger seeds absorbed more than smaller seeds. It has been reported that consumers can pay higher amounts for larger beans (Faye et al., 2004). Previous consumer demand analysis was based on raw bean seeds' physical quality. Based on clumping, slightly few clumps, moderate clumps to moderately few clumps were recorded for all the accessions. For the TVUs the brine was slightly cloudy to clear while TVUs 18, 19, 30, 31, 32, 43, 140 and 73 were moderately cloudy. The TVNUs had moderately cloudy to very clear brine (3.0-7.0). The market class had neither clear nor cloudy to clear brine on a scale of 4.0-60. Based on sensory evaluation, accessions were like slightly to like very much on the scale of 5.0-7.0 for the TVU accessions. Except for TVUs 20, 21, 27, 33, 22, 53, 14 and 77 having dislike slightly to dislike very much. For TVNUs, seeds were disliked or like moderately on a scale of 1.0-6.0. While seeds were like slightly to like very much (5.0-7.0) for the market class varieties. Some of the TVUs and the market class varieties have more splits in their seeds, unlike the TVNU accessions.

Accessions with promising canning quality were selected based on post canning parameters on the scale of 1.0-7.0. TVU-2, TVU-13, TVU-26, TVU-37, TVU-38, TVU-45, TVU-50 and TVU-51 possessed good canning qualities. This selection was based on overall canning quality assessment, including sensory evaluation. Sensory evaluation showed that panellists had well-defined preferences for particular cowpea related to their colour, taste, appearance, size, mouth-feel, wholesomeness, flavor and overall acceptance. These canning quality characteristics are of great importance in the canning industry as well as those related to the appeal and taste of canned beans (Khanal et al, 2015). According to Casanas et al. (2002), Mkanda (2007) and Makonnen (2012) trained evaluators has the ability to detect the disparities in sensory quality characteristics among cooked beans genotypes. The diversity of accession evaluated for the agronomic parameter, cooking time, and canning qualities were significant.

CONCLUSION

This study showed that the cowpea accessions adapted to the three seasons (early wet, late wet and dry seasons), however, optimal performance was observed in late wet followed by dry season. Based on the cooking time evaluation, the following accessions possessed shorter cooking time of 50 minutes while four of the market class lines had cooking times of 51 minutes (TVU-2, TVU-8, TVU-9, TVU-13, TVU, 21, TVU29, TVU-36, TUV-38 and iron white, akara bean, iron brown and honey bean). The wild *Vigna* species had the longest cooking time of 133 and 193 minutes. Also, results from the canning quality assessment showed that nine of the cowpea breeders' seeds including TVU-2, TVU-13, TVU-26, TVU-37, TVU-38, TVU-45, TVU-50 and TVU-51 possessed promising canning characteristics. It is recommended that the selected accessions for better agronomic and culinary quality traits can be used for cowpea breeding programmes. Also, it was observed that both the sensory panel and tactile methods are laborious and takes time. A texture analyzer and Mattson cooker, first developed by S. Mattson in 1946 can be used in the study of cooking time and caning quality of cowpea.

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Author contribution:

Josephine Ukomadu wrote the design of the experiment, data analysis and the manuscript. Agronomic Data was collected and analyzed by Odogwu, Blessing Adanta. The cooking time evaluation manuscript was written and reviewed by Agbagwa Ikechukwu Ozoemenam.

REFERENCES

Adebooye, C. O., & Vasudeva Sing, V. (2007). Effect of Cooking on the Profile of Phenolics, Tannins, Phytate, Amino Acid, Fatty acid and Mineral Nutrients of Whole-Grain and Decorticated Vegetable Cowpea (*Vigna unguiculata* l. walp). *Journal of Food Quality 30*, 1101–1120.

Afoakwa, E. O., Sefa-Dedeh, S., & Cornelius, B. (2002). Optimization of the nutritional quality characteristics of cowpea-fortified nixta- malized maize using computer-generated response surface models. *The South African Journal of Clinical Nutrition, 15*(2), 17–19.

Afoakwa, E. O., Yenyi, S. E., & Sakyi-Dawson, E. (2006). Response Surface Methodology for Optimizing the Pre-processing Conditions during Canning of a Newly Developed and Promising Cowpea (*Vigna unguiculata*) Variety. *Journal of Food Engineering. 73*, 346–357.

Amonsou, E., Sakyi-Dawson, E., & Saalia, F. (2010). Effects of cowpea flour fractionation on sensory qualities and acceptability of kpejigaou (a griddled cowpea paste food). *Journal of Food Quality*, *33*, 61-78. http://197.255.68.203/handle/123456789/1236

Appiah, F., Asubuo, Y. J., & Kuma, P. (2011). Physicochemical and Functional Properities of Beans Flour of Three Cowpea (*Vigna unguiculata* L. Walp) Varieties in Ghana. *African Journal of Food Science*, *5*(2), 100-104.

Ashogbon, A. O., & Akintayo, E. T. (2013). Isolation Characterization of Starches from two Cowpea (*Vigna unguiculata*) Cultivars. *International Food Research Journal*. *20*, 3093–3100.

Bassinello, P. Z. (2008). Qualidade na escolha de variedades de feijão para o mercado consumidor. Atualidades em micotoxinas e armazenagem qualitativas de grãos ll. Florianópolis: Imprensa Universitária. 586p.

Casanas, F., Pojula, M., Bosch, L., Sanchez, E., & Nuez, F. (2002). Chemical basis for the low sensory perception of the Ganxet bean (Phaseolus vulgaris L.) seed coat. *Journal of the Science of the Food and Agriculture 82*, 1282-1286.

Cavalcante, R. B. M., Araújo, M. A. D. M., Rocha, M. D. M., & Moreira-Araújo, R. S. D. R. (2017). Effect of thermal processing on chemical compositions, bioactive compounds, and antioxidant activities of cowpea cultivars. *Revista caatinga, 30*(4), 1050-1058. doi: 10.1590/1983-21252017v30n426rc.

Demooy, B. E., & Demooy, C. J. (1990). Evaluation of cooking time and quality of seven diverse cowpea (Vigna unguiculata (L.) Walp.) varieties. *Int. J. Food Sci. Technol. 25*, 209-212.

Demooy, B. E., & Demooy, C. J. (1990). Evaluation of cooking time and quality of seven diverse cowpea (Vigna unguiculata (L.) Walp.) varieties. *Int. J. Food Sci. Technol. 25*, 209-212.

Faye, M., Fulton, J., Ibro, G., Dushwaha, S., & Lowenberg-DeBoer, J. (2004). Developing cowpea market opportunities in West Africa. Bean/Cowpea CRSP: Regional project research and training annual technical progress reports. Bean/Cowpea CRSP 2004: 5-13.

Food and Agriculture Organisation, (2012). FAOSTAT Gateway. *Archived September 30*, 2019.

Hamid, S., Muzaffar, S., Wani, I. A., Masoodi, F. A., & Bhat, M. M. (2016). Physical and cooking characteristics of two Cowpea cultivars grown in temperate Indian climate. *Journal of the Saudi Society of Agricultural Sciences*. *15*(2), 127-134.

Joseph, O. A., Henriëtte, L. K., & Taylor, J. R. N. (2011). Evaluation of the functional quality of cowpea-fortified traditional African sorghum foods using instrumental and descriptive sensory analysis. LWT - *Food Science and Technology [online], 44*(10), 2126–2133.

Khanal, R. A. J., Burt, L., Woodrow, P., Balasubramanian, & Navabi, A. (2015). Genotypic association of parameters commonly used to predict canning quality of dry bean. *Crop Sci. 54*, pp: 2564- 2573.

Lobell, D. B., Burke, M. B., Tebaldi, C., Mastrandrea, M. D., Falcon, W. P., & Naylor, R. L. (2008). Prioritizing Climate Change Adaptation Needs for Food Security in 2030. *Science (New York, N.Y.). 319*, 607-610.

Loggerenberg, M. V. (2004). Development and Application of a Small-scale Canning Procedure for the Evaluation of Small White Beans (*Phaseolus vulgaris*). Ph.D. Thesis in the Faculty of Natural- and Agricultural Sciences, Department of Microbial-Biochemical and Food Biotechnology university of the Free State Bloemfontein. 1-80.

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

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

Muranaka, S., Shono, M., Myoda, T., Takeuchi, J., Franco, J., Nakazawa, Y., Boukar, O., & Takagi, H. (2016). Genetic diversity of physical, nutritional and functional properties of cowpea grain and relationships among the traits. Plant Genetic Resources: *Characterization and Utilization. 14*(1), 67–76.

Negri, V., Floridi, S., & Montanari, L. (2001). Organoleptic and chemical evaluation of Italian cowpea (*Vigna unguiculata* subsp. *unguiculata* cv gr. unguiculata (l.) walp.) landraces from a restricted area. *Ital J Food Sci. 13*, 383-390.

Ngure, D., Kinyua, M., & Kiplagat, O. (2021). Evaluation of Cooking Time and Organoleptic Traits of Improved Dolichos (*Lablab purpureus* (L.) sweet) Genotypes. *Afric. Jol. of Food Sci*.

Njau, N. S. (2016). Selection for Yield Potential, Disease Resistance and Canning Quality in Runner and Snap Bean Lines and Populations. A Thesis submitted in partial fulfillment of the requirement for the award of master of science degree in Plant Breeding and Biotechnology.

Obasi, N. E., Unamma, N. C. 1., & Nwofia, G. E. (2014). Effect of Dry Heat Pre-Treatment (Toasting) on the Cooking Time of Cowpeas (*Vigna unguiculata* L. Walp). *Nigerian Food Journal. l32*(2), 16 – 24.

Odogwu, B. A., Uzogara, M. O., Worlu, H., & Agbagwa, I. O. (2021). Factors affecting stakeholders preferences for cowpea grains in selected parts of Nigeria. *Afri. Jol of Food, Agric., Nutri., and Dev. 21*,(3).

Olapade, A., Okafor, G. I., Ozumba, A. U., & Olatunji, O. (2002). Characterisation of common Nigerian cowpeas *(Vigna unguiculata* L. Walp*)* varieties. *Journal of Food Engineering 55*, 101 – 105.

Owusu, D. K., Newman, F. C., & Gabriel, A. G. (2018). Evaluation of Physical and Cooking Characteristics of Five Improved Lima Beans. *Wld. Jol of Food Sci. and Tech. 2*(2).

Pedrosa, M. M., Cuadrado, C., Burbano, C., Muzquiz, M., Cabellos, B., Olmedilla-Alonso, B., & Asensio-Vegas, C. (2014). Effects of Industrial Canning on the Proximate Composition, Bioactive Compounds contents and Nutritional Profile of Two Spanish common Dry Beans (*Phaseolus vulgaris L.*). *Food Chemistry*. *66*, 68-75.

Sasikala, V. B., Ravi, R., & Narasimha, H. V. (2011). Textural changes of green gram (Phaseolus aureus) and horse gram (Dolichos biflorus) as affected by soaking and cooking. *J. Texture Stud. 42*, 10-19.

Sefa-Dedeh, S., Frimpong, K., Afoakwa, E. O., & Sakyi-Dawson, E. (2000). Cowpea fortification of traditional foods. Paper Presented at the World Cowpea Research Conference III. September 4–7, Ibadan, Nigeria.

Siddiq, M., & Uebersax, A. M. (2013). Dry Beans and Pulses, Production, Processing, and Nutrition. *Journal of Experimental Agriculture*, *49*(3), 450-465.

Silva, D, O. M., Santos, A. F. C., Seido, L. S., Coelho, C. P. W., & De Aquino, L. A. D. (2017). Retention of Proteins and Minerals After Cooking in Cowpea Genotypes. gropec. Trop., Goiânia.

Taiwo, A. K., Akanbi, T. C., & Ajibola, O. O. (1997). Establishing Processing Conditions for Canning Cowpea Seeds in Tomato Sauce. *International Journal of Food Science and Technology*. *32*, 313–324.

Taiwo, K. A., Akanbi, C. T., & Ajibola, O. O. (1998). Regression relationships for the soaking and cooking properties of two cowpea varieties. *J. Food Eng. 3*, 331–344.

Tariku, S. (2018). Genotype by Environment Interaction and Stability Analysis in Cowpea [*vigna unguiculata* (l.) walp] Genotypes for Yield in Ethiopia. A Thesis Submitted to the School of Plant Sciences, Postgraduate Programs Directorate. HARAMAYA University Master OF Science IN Agriculture.

Trust. K. (2012). Development of Inclusive Markets in Agriculture and Trade (DIMAT). UNDP, 1–48. Retrieved from PovRed_Value Chain Analysis Report Common Beans.

Uebersax, M. A. (2006). Dry Edible Beans: Indigenous Staple and Healthy Cuisine. Forum on Public Policy: *A Journal of the Oxford round table*. 7-8. Retrieved 22/05/202

Wang, N., Daun, J. K., & Malcolmson, L. J. (2003). Relationship between physicochemical and cooking properties, and effects of cooking on antinutrients, of yellow field peas (*Pisum sativum*). *J Sci Food Agric 83*, 1228–1237.

Wiesinger, J. A., Cichy, K. A., Glahn, R. P., Grusak, M. A., Brick, M. A., Thompson, H. J., & Tako, E. (2016). Demonstrating a nutritional advantage to the fast-cooking dry bean (*Phaseolus vulgaris* L.). *Journal of Agricultural and Food Chemistry*, *64*(45), 8592–8603.

Yeung, (2007). Evaluation of Legume Cooking Characteristics Using a Rapid Screening Method. A Master Degree Thesis. Texas A and M University USA. pp. 1.

Zanovec, M., O'Neil, E. C., & Nicklas, A. T. (2011). Comparison of Nutrient Density and Nutrientto-cost Between Cooked and Canned Beans. *Food and Nutrition Sciences*. *2*, 66-73.