DRF-356
[1-8]

RESEARCH ARTICLE Asian Journal of Dairy and Food Research

Physicochemical, Cooking Quality and Sensory Acceptability of Three Cowpea Varieties Grown in Botswana

Oduetse Daniel Gopadile[1], Rosemary Kobue-Lekalake[2], Boitumelo Mokobi[2], Geremew Bultosa[2]

10.18805/ajdfr.DRF-356

ABSTRACT

Background: Information on the physicochemical, cooking and sensory qualities of cowpea seeds are required for nutrition information, to design processing and for consumer acceptance. In view of this, three cowpea varieties (Tswana, Blackeye and ER7) grown in Botswana were evaluated.

Method: Proximate compositions, physical, gelatinization and sensory properties respectively were evaluated following AOAC, conventional, Amylograph and on 7-point hedonic sensory acceptability scale.

Result: Significant variations ($p<0.05$) were observed in fat, fiber, ash and available carbohydrate (CHO) contents, length, thickness, hundred seeds weight (HSW), hydration capacity, hydration index, cooking time, flour starches maximum gelatinization temperature (Tm,°C) and viscosity at Tm. The percentage moisture, protein, fiber, fat, ash and available carbohydrate contents ranged 9.5-10.1, 21.7-22.8, 2.3-2.6, 1.1-2.0, 2.1-3.0 and 59.4-62.3, respectively. Initial gelatinization temperature (To,°C) and Tm (°C) were ranged 71.3(ER7)-73.7(Tswana) and 83.0(ER7)-84.7(Blackeye), respectively. Significant ($p<0.05$) variations in Tm and viscosity at Tm were observed because of differences in water uptake, swelling and thickening ability at high temperature. Longest cooking time was recorded for Tswana (43.57 min) while shortest was for Blackeye (36.10 min). Tswana recorded a longer cooking time probably because of low water hydration capacity, small seed size and low HSW. There was no significant difference in the sensory liking of the cooked cowpea seeds and were rated from slightly to moderately like. Cowpeas of high protein and fiber contents, short cooking time and high thickening ability on cooking are preferred for healthy diets. In terms of cooking time and thickening ability, Tswana variety appeared poor. Shorter cooking time, high protein content and high thickening ability of Blackeye cowpea is more acceptable. The ER7 is preferred for its large seed size.

Key words: Amylograph gelatinization, Cooking time, Cowpea, Physical, Proximate, Sensory.

INTRODUCTION

Cowpea [*Vigna unguiculata* (L.) Walp] is a legume of the Fabaceae family which is also known by different names in different regions: west Africa (wake and ewa), Brazil (caupi), United States (blackeyed peas, field peas, crowder peas, southern peas, pinkeyes), India (lobia), China (long bean, asparagus bean) (Narayana and Angamuthu, 2021). Cowpea is believed to have originated in Africa and is widely cultivated in semi-arid and arid regions including Botswana because of its adaptation to hot, erratic and low rainfall conditions (Mashungwa *et al.,* 2019). In Botswana, cowpeas are mostly grown in the central district area, around Gaborone, Francistown, Maun and in the southern part of the country (Mashungwa *et al.,* 2019). The cowpea varieties cultivated include ER7, Black eye and Tswana. ER7 is a hybrid genetically made to suit the harsh environmental conditions and is also resistant to some diseases (DAR, 1983). The ER7 is a short- season determinative variety with an erect growth habit, medium size seeds with cream-colored rough seeds coat (Demooy and Demooy, 1989; DAR, 1983). Blackeye is also a short- seasonal indeterminate variety with semi-spreading habit. The seed is of medium size with white and black eye and wrinkled seed coat. Tswana is tan in color, medium seed size and spreading with indeterminate growth habit (DAR, 1983). In Botswana, young leaves, immature pods, green and dry seeds are consumed after cooking. Cowpea plays an important role in the economy and diet of the populations since they provide a cheap high protein (23-32%) also significant carbohydrates, dietary fibers, B-vitamins and minerals (Affrifah *et al.,* 2021a; Jayathilake *et al.,* 2018; Gonçalves *et al.,* 2016). The protein is rich in essential amino acids (g/100g proteins) lysine (7.3-8.7), leucine (6.5-8.5), isoleucine (4.2-5.5) and threonine (3.9-5.1) but are limited in sulfur containing amino acids cysteine (0.8-1.1) and methionine (1.3-2.1) (Jayathilake *et al.,* 2018).

[1]Bolux Milling (PTY) Ltd, Plot 10247, Broadhurst Ind, Gaborone, Botswana.

[2]Department of Food Science and Technology, Botswana University of Agriculture and Natural Resources, Private Bag 0027, Gaborone, Botswana.

Corresponding Author: Geremew Bultosa, Department of Food Science and Technology, Botswana University of Agriculture and Natural Resources, Private Bag 0027, Gaborone, Botswana. Email: geremewbultosa@gmail.com

How to cite this article: Gopadile, O.D., Kobue-Lekalake, R., Mokobi, B. and Bultosa, G., (2024). Physicochemical, Cooking Quality and Sensory Acceptability of Three Cowpea Varieties Grown in Botswana. Asian Journal of Dairy and Food Research. DOI: 10.18805/ajdfr.DRF-356.

Submitted: 14-9-2023 **Accepted:** 05-04-2024 **Online:** 10-06-2024

Cowpeas are also recognized as good sources of health promoting bioactive compounds such as phenolic compounds (Teka *et al.,* 2020) and bioactive peptides (Awika and Duodu, 2017). Consumption of legumes like cowpea has been related to many beneficial physiological effects in controlling and preventing various metabolic related diseases such as diabetes mellitus two, coronary heart disease and colon cancer because they contain low amount of fat, high dietary fibers, phenolic compounds, and bioactive peptides (Mendes *et al.,* 2023; Jayathilake *et al.,* 2018).

Nutritional and functional properties of cowpeas are influenced by food processing conditions used such as soaking, roasting, cooking, autoclaving, micronizing, sprouting and fermentation. Such processes are used to suppress anti-nutrients such as trypsin inhibitors, phytic acids, condensed tannins, hydrogen cyanide, raffinose type oligosaccharides, lectins to improve digestibility and bioavailability of nutrients (Kalpanadevi and Mohan, 2013). The cooking process involves water hydration, water uptake into flour starch granules and on heating leads to gelatinization of starch granules, thermal denaturation of proteins, deactivation of antinutritional factors resulting into softer palatable grains texture (Affrifah *et al.,* 2021b; Coffigniez *et al.,* 2019). Flour starches gelatinization temperature, cooking time, viscosity development on cooking gives an indication of digestibility and cooking quality since these factors are responsible for consumers choice of a particular food (Madodé *et al.,* 2013). Cooking influences sensory acceptance. However, information on proximate composition, physical properties, cooking characteristics and sensory acceptability of cowpea seed varieties grown in Botswana is limited to ascertain their consumer market acceptance and end use as meal. The objective of this work was to evaluate the physicochemical, cooking quality and sensory acceptability variations of three cowpea varieties grown in Botswana. Therefore, in this paper, the proximate composition, physical, flour starches gelatinization, cooking and sensory characteristics for the three cowpea seed varieties are reported.

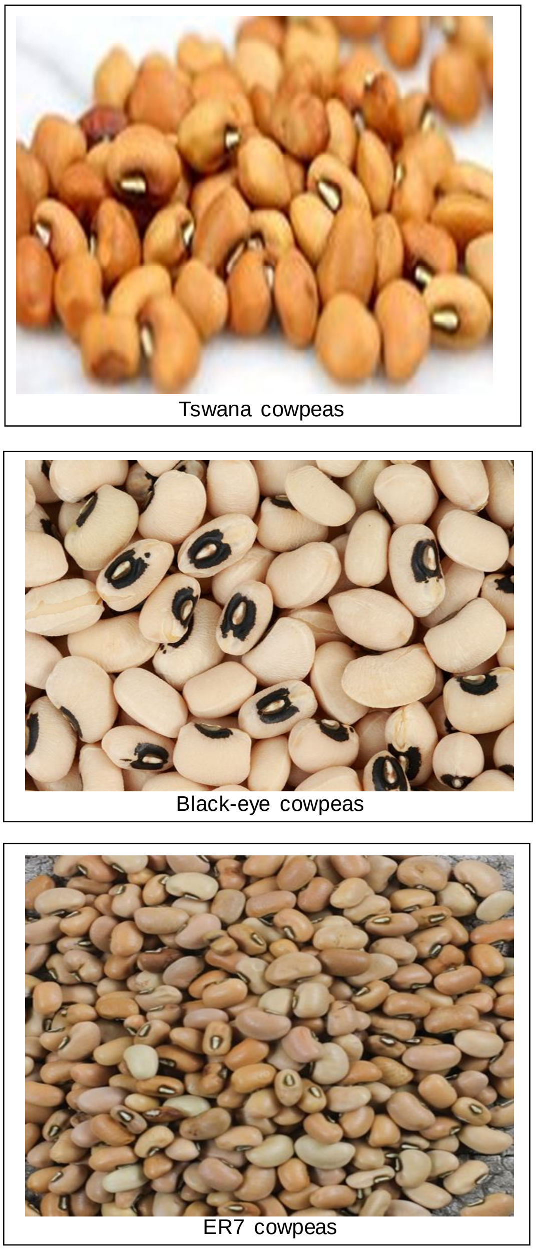

Fig 1: The three cowpea varieties studied.

MATERIALS AND METHODS

Cowpeas seeds sample

The three cowpea seed varieties (Tswana, Black-eye and ER 7) (Fig 1) were purchased from Botswana Agricultural Marketing Board (BAMB) in Gaborone.

Physical properties of cowpea seeds

Seed size

The length, width and thickness of ten random manually selected dockage free seeds were measured using Vernier caliper (± 0.01 mm) in triplicate and the results were expressed on 12.5% moisture basis (Henshaw, 2008).

Hundred seed weight (HSW)

It was determined by measuring mass (± 0.001 g) of 100 randomly selected sound seeds of dockage free sample in triplicate on electronic balance and the results were expressed on 12.5% moisture basis (Hamid *et al.,* 2016).

Hydration capacity and hydration index

Cowpea 5 g were counted and soaked in 50 mL of distilled water in a measuring cylinder covering with an aluminum foil for 24 h at room temperature (20 ± 2°C), after that, water was drained, superfluous water on the seeds surface was removed by blotting with lint free tissue paper and the weight of the swollen seeds was measured (Hamid *et al.,* 2016). The hydration capacity per seed and hydration index were calculated (Sood *et al.,* 2002).

$$\text{Hydration capacity (g/seed)} = \frac{\text{Weight after soaking-Weight before soaking}}{\text{Number of seeds}}$$

$$\text{Hydration index} = \frac{\text{Hydration capacity per seed}}{\text{Weight of one seed}}$$

Proximate composition analysis

Sample preparation

The three cowpea seeds varieties were milled to flour using Cross Beater Mill (SK 300, RETSCH, Germany) fitted with 500 µm sieve, packed in zip lock plastic bag covered with paper board and stored in refrigerator (4°C) until used for analysis. *Moisture content* was determined by oven drying method (AOAC, 1998 Method No 925.10). *Crude protein content* was determined by micro-Kjeldahl (DKL 20 and UDK 149, VELP Scientifica, Italy) method of nitrogen content analysis (AOAC, 1998 Method No 920.87).

$$\% \text{ Protein} = \% \text{ N} * 6.25$$

Crude fat content

Determined by Soxhlet extraction using petroleum ether (AOAC, 1998 Method No 920.39).

Crude fiber content

Determined after digestion with dilute sulfuric acid (1.25%) and dilute sodium hydroxide (1.25%), subsequent sieving (75 micrometer), washing, drying and ignition to subtract ash from fiber (AOAC, 1998 Method No 962.09).

Ash content

Determined after carbonization and ignition (AOAC, 1998 Method No 923.03).

Available carbohydrate

Available carbohydrate*(mostly starch) content* was determined by difference as 100 - [%protein + % fat + % moisture + % ash + % fiber] (Monro and Burlingame, 1996).

Amylograph gelatinization properties

The gelatinization properties were analyzed by mixing 80.0 g of each cowpea flour (14% moisture basis) sample with 450 mL distilled water at a heating rate of 1.5°C/min from 30°C to the maximum gelatinization temperature using Brabender Amylograph®E (Brabender® GmbH and Co. KG, Duisburg, Germany) in a duplicate (Brabender® GmbH *and* Co. KG., 2005). From the Amylogram, initial gelatinization temperature (To,°C), temperature at maximum gelatinization (Tm,°C), viscosities (AU) at To and Tm were evaluated using Amylograph® Data Correlation version: 4.1.4 software.

Cooking quality

The cowpea seeds were soaked in distilled water for 12 h at room temperature. Soaking was done to reduce the cooking time and to aid uniform cooking of cowpeas. The height of water level used for soaking and cooking was about 1.5 cm above the soaked seeds. After draining out the soaking water, the seeds were cooked in distilled water in a stainless-steel pot until they became soft when pressed between the fingers indicating cooking time (min).

Sensory evaluation

The panelists for sensory evaluation were recruited after getting their consent for participation from Botswana University of Agriculture and Natural Resources (BUAN) staff and students based on their familiarity with cooked cowpea seeds consumption. Prior to the conduct, orientation was given to the panels on how to conduct the sensory acceptability evaluation. Those in unhealthy conditions were excluded. About 500 g of whole cowpea seeds were cooked until tender. After cooling to room temperature, about 50 g of cooked cowpea sample labelled randomly with 3-digit codes were evaluated by 20 panelists for sensory acceptability of aroma, color, texture and overall acceptability using a 7-point hedonic scale (1 = extremely dislike, 2 = moderately dislike, 3 = slightly dislike, 4 = neither like or dislike, 5 = slightly like, 6 = moderately like and 7 = extremely like) (Lawless *and* Heymann, 2010). Water was used to cleanse their palate before and after tasting each sample to avoid sample carryover.

Statistical data analysis

A triplicate data and for amylograph gelatinization a duplicate data was analyzed by one-way Analysis of Variance (ANOVA) using IBM Corporation (2017) SPSS® Statistics Version 25 (USA). For each case, a mean value and standard deviation were calculated. The means difference was separated by Tukey's honest significance test at $p<0.05$.

RESULTS AND DISCUSSION

Physical properties of cowpea seeds

The cowpea seeds physical properties evaluated are given in Table 1. Length and thickness of the varieties had varied significantly ($p<0.05$) from 9.4 to 11.4 mm and 2.4 to 3.4 mm, respectively. However, insignificant difference ($p>0.05$) in their seed width from 4.6 to 5.3 mm were observed. Similar insignificant variations for seeds size was reported for 78 cowpea genotypes in Ghana (Egbadzor *et al.,* 2013). The results showed seed size of ER7 cowpea variety appeared largest. Almost similar seed length, width and thickness for 78 cowpea genotypes (5.7-9.9, 4.9-7.5 and 2.3-5.8, respectively) in Ghana (Egbadzor *et al.,* 2013) and for 28 cowpea varieties (5.0-10.0, 3.8-6.9 and 3.3-5.9, respectively) from Nigeria and USA origins (Henshaw, 2008) were reported even though varieties in this study appeared toward long seed size range. The HSW for the cowpea varieties showed significant difference ($p<0.05$) (ER7 > Blackeye > Tswana). The HSW found were in the range of 10.1-25.8 g for 28 cowpea varieties reported from Nigeria and USA origins (Henshaw, 2008). Knowledge of seed size and seed weight of the cowpea seeds are important quality indicator for variety identification, consumers choices and to design equipment for processing (for harvesting, threshing, cleaning, separation, transportation and packaging). Seed size influences water absorption on soaking and thereby cooking characteristics. According to Sobukola and Abayomi (2011) the dimensions of cowpea beans and their HSW give an indication of the space the seeds would occupy and their bulkiness. In this instance, since the HSW of Blackeye and ER7 were not significantly different (p>0.05), the demand for packing and transportation would be similar. According to Egbadzor *et al.* (2013) seed thickness and HSW were important indicators for cowpea genotypes seed size differences, and in the West Africa the most preferred trait is the one with high seeds size. According to Sombié *et al.* (2021) seed size was positively correlated to starch content but negatively with total phenolic content. In this regard the highest seed size ER7 is more preferred whereas Tswana is probably low in starch contents as reflected from its small seed size and low HSW.

Proximate composition

The proximate composition results showed insignificant (p>0.05) variations on moisture and protein contents (Table 2). However, significant variations (p<0.05) were observed in their crude fiber, fat, ash and available carbohydrate contents. The moisture contents were ranged from 9.5% to 10.1%, which is below the maximum moisture content (12%) recommended for cowpea safe storage (Aboagye *et al.,* 2017). The moisture content can influence the cowpea seeds storage stability, duration and cost of transportation. High moisture content for cowpea seeds can result into insects and moulds attack that can lead to seeds huge loss (Silva *et al.,* 2018). The protein contents were ranged from 21.71 to 22.83% and are within the range 17.4-28.3% reported for 30 Brazilian cowpea genotypes (Carvalho *et al.,* 2012). For Tswana and Blackeye are within the range for cowpea seed accessions (22.5-25.6%) reported from Bulgaria (Antova *et al.,* 2014). In general legumes have high protein contents and are regarded as an important source of proteins. Cowpea proteins are rich in lysine to complement cereal grains for human nutritional needs of essential amino acids (Affrifah *et al.,* 2021a; Gonçalves, *et al.,* 2016).

The three cowpea varieties crude fiber content were ranged from 2.3 (Blackeye)-2.6% (Tswana) and are within the range 1.7-3.0% reported for four cowpea seed accessions cultivated in Bulgaria (Antova *et al.,* 2014). The high crude fiber content in the Tswana could be related to its small seed size and low HSW of which most probably filling by starch in the cotyledon is limited that contributes to high proportion of fiber (Affrifah *et al.,* 2021a). The crude fiber content only estimates the insoluble dietary fibers cellulose, lignins and some hemicellulose, whereas compounds that are classified as dietary fibers are diverse. For example, dietary fibers content for Blackeye was reported as 10.6% (USDA, 2018). Adequate dietary fiber intake from foods is important to modulate blood glucose and cholesterol levels, suppress cancer and promote positive gut health in an individual (Li and Komarek, 2017). The crude fat contents had ranged from 1.1 (Blackeye) to 2.0% (Tswana) and similar in the range 0.49 to 1.94 % were reported for two cowpea varieties grown in temperate Indian (Hamid *et al.,* 2016), 1.3 to 1.9% for four cowpea seed accessions cultivated in Bulgaria (Antova *et al.,* 2014) and 1.0 to 1.6% for 30 Brazilian cowpea genotypes (Carvalho *et al.,* 2012). The fat content found was low and this informs cowpeas are generally suitable for low fat formulations in the diet. The ash contents ranged from 2.1 to 3.0% and similar ash contents were reported for two cowpea varieties (1.98 to 2.81%) grown in the temperate Indian climate (Hamid *et al.,* 2016), but were lower than 3.2 to 3.7% reported for four cowpea seed accessions cultivated in Bulgaria (Antova *et al.,* 2014) and for 30 Brazilian cowpea genotypes (3.3 to 4.6%) (Carvalho *et al.,* 2012). The ash content is an indicator of

Table 1: Physical properties of three cowpea varieties grown in Botswana on 12.5% moisture basis.

Variety	Length (mm)	Width (mm)	Thickness (mm)	HSW (g)
Tswana	9.4±0.5b	4.8±0.9a	2.9±0.1ab	18.9±0.3b
Blackeye	9.6±0.3b	4.6±0.2a	2.4±0.2b	21.6±0.3a
ER7	11.4±0.3a	5.3±0.4a	3.4±0.5a	21.9±0.3a
Range	9.4-11.4	4.6-5.3	2.4-3.4	18.9-21.9
p<0.05	0.001	0.312	0.016	0.000

Where HSW = Hundred seed weight. Means in the same column followed by different letters are significantly different at p< 0.05.

Table 2. Proximate composition of three cowpea varieties grown in Botswana.

Variety	Moisture (%)	Protein (%)	Crude fiber (%)	Fat (%)	Ash (%)	CHO (%)
Tswana	10.1±0.3a	22.8±1.0a	2.6±0.0a	2.0±0.2a	3.0±0.2a	59.4±0.7b
Blackeye	9.7±0.2a	22.5±0.8a	2.3±0.1c	1.1±0.2b	2.1±0.1b	62.3±0.9a
ER7	9.5±0.5a	21.7±0.6a	2.4±0.0b	2.0±0.1a	2.1±0.2b	62.3±0.2a
Range	9.5-10.1	21.7-22.8	2.3-2.6	1.1-2.0	2.1-3.0	59.4-62.3
p<0.05	0.196	0.300	0.00	0.000	0.000	0.003

Where CHO = Carbohydrates. Means in the same column followed by different letters are significantly different at p<0.05.

mineral nutrient contents and among legumes, cowpea is generally regarded as good sources of mineral nutrients (Jayathilake *et al.,* 2018) even though the contents can be varied depending on the soil type, cowpea cultivars and growing climates (Santos and Boiteux, 2013). The available carbohydrate contents were ranged from 59.4 to 62.3% and the lowest was recorded for Tswana. There was insignificant difference (p>0.05) on the available carbohydrate contents of Blackeye and ER7 cowpea varieties. Similar carbohydrate contents 60.53 to 62.45% for two cowpea varieties (Hamid *et al.,* 2016), for 28 cowpea varieties (57.2 to 64.6) of Nigeria and USA origins (Henshaw, 2008) and 60.03% for common Blackeye cowpea seeds (USDA, 2018) were reported. The high available carbohydrate and protein contents are important toward reduction of protein energy malnutrition in semi-arid and resource poor regions.

Cooking properties

The hydration capacity and hydration index of the cowpea seeds were varied significantly (p<0.05) and were ranged: 0.19 to 0.21 g/seed and 0.91 to 1.04, respectively (Table 3). The hydration capacity and hydration index respectively were reported as 0.03 g/seed and 0.9 by Tresina *and* Mohan (2012) and 0.05 to 0.1 g/seed and 0.53 to 0.70 by Hamid *et al*. (2016). The hydration capacity indicates the water uptake of the seeds on soaking and is influenced by the seed coat texture, nature of testa, hilum and seeds micropyle (Toan Do and Singh, 2019). The study showed that the hydration capacity of Tswana seeds is low. Normally, higher hydration capacity is associated with a shorter cooking time (Pramiu *et al.,* 2015). Cooking time involves the process of hydration during which water diffuse into the seed cells through hilum and micropyle, imbibition of seeds, water uptake into the amorphous portions of starch granules and upon heating follows thermal denaturation (coagulation) of proteins and swelling of starch granules leading to starch granules gelatinization of cooked tenderized seed texture (Kinyanjui *et al.,* 2015).

The cooking time of the cowpea seeds showed significant differences (p<0.05) and ranged from 36.1 (Blackeye) to 43.6 min (Tswana). Tswana variety showed long cooking time most probably because of its poor water hydration capacity (Table 3). The cooking time found for the three cowpea varieties were in the reported range 36 to 46 min (Demooy and Demooy, 1990) and 29.77 to 64.67 min (Hamid *et al*., 2016). Cooking time gives an indication of cooking quality since it is one of the most important factors responsible for consumers' choice. Short duration of cooking time is desirable quality because it saves time and energy cost for cooking and in this aspect the Blackeye cowpea appeared best. The cooking time was indicated to be influenced by variety, quality of cooking water, soaking time, soaking temperature, and cooking temperature (Coffigniez *et al.,* 2019).

Amylograph gelatinization properties

The initial (To), maximum (Tm) gelatinization temperatures, and viscosities evaluated at To and Tm from Brabender Amylogram gelatinization graphs (Fig 2) are given in Table 3. The To and Tm for the three-cowpea flour starch granule varieties ranged from 71.3 to 73.7°C and 83.0 to 84.7°C, respectively. Insignificant variations (p>0.05) were observed on To. However, significant variations (p<0.05) were observed on their Tm and viscosities at their Tm. Using Brabender Visco-Amylograph, a pasting temperature (approx. gelatinization temperature) 77 °C was reported for cowpea flour starches (Adebooye and Singh, 2008). Similar to this work, gelatinization temperature To (70.5 to 72.7 °C),

Table 3: Hydration characteristics, cooking time and Amylograph gelatinization temperature of three cowpea varieties grown in Botswana.

Variety	Hydration capacity (g/seed)	Hydration index	Cooking time (min)	To (oC)	Tm (oC)	Vis.o (AU)	Vis.m (AU)
Tswana	0.19±0.00b	1.04±0.06a	43.6±0.4a	73.7±1.2a	84.2±0.6ab	10.5±0.7a	4040±252b
Blackeye	0.21±0.01a	0.94±0.00b	36.1±0.4c	73.0±0.2a	84.7±0.1a	10.0±1.4a	6181±313a
ER7	0.20±0.00ab	0.91±0.00b	39.5±0.6b	71.3±0.4a	83.0±0.1b	11.0±0.0a	5569±305a
Range	0.19-0.21	0.91-1.04	36.1-43.6	71.3-73.7	83.0-84.7	10.0-11.0	4040-5569
p<0.05	0.014	0.006	0.000	0.096	0.034	0.604	0.011

Where: To = initial gelatinization temperature, Tm = maximum gelatinization temperature, Vis.o = viscosity at initial gelatinization temperature, Vis.m = viscosity at maximum gelatinization temperature. Means in the same column followed by different letters are significantly different (p<0.05).

Table 4: Sensory acceptability of three cowpea varieties grown in Botswana.

Variety	Aroma	Color	Texture	Taste	Overall acceptability
Tswana	5.45±1.32a	4.45±0.90a	5.45±1.40a	5.45±1.79a	6.05±1.15a
Blackeye	5.50±1.43a	5.15±1.27a	5.60±1.35a	5.15±1.35a	5.80±1.24a
ER7	5.00±1.38a	4.95±1.46a	4.85±1.93a	5.20±1.47a	5.95±1.36a
p<0.05	0.45	0.300	0.291	0.743	0.817

Means in the same column followed by the same letters are not significantly different at p>0.05.

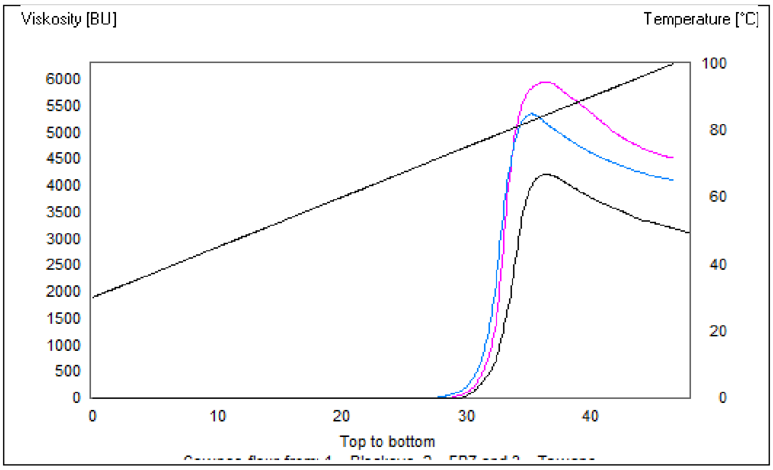

Fig 2: Brabender Amylogram gelatinization graph of three cowpea varieties grown in Botswana.

but somewhat less on the peak (Tp = 75.4°C) and conclusion gelatinization temperatures (Tc = 81°C) were reported for cowpea starches using differential scanning calorimeter (DSC) (Hoover *et al.,* 2010). In other works, To, Tp and Tc, respectively in the range 63.8 to 69.0°C, 69.6 to 75.3°C and 82.3 to 84.6°C by using DSC and pasting temperature (Rapid from Rapid Visco Analyzer) of 74.7 to 79.9°C were reported for cowpea starches (Kim *et al.,* 2018). The process of starch granules gelatinization involves uptake of water, swelling, disruption of hydrogen bonding, crystallites melting, disappearance of Maltese cross, disintegration and leaching of starch macromolecules (particularly amylose) form the starch granules in the cooking medium, viscosity (thickening) developments and leading to digestible meal (BeMiller and Whistler, 2009). Starches are available for amylase enzymes digestion after their gelatinization (Joye, 2019). The gelatinization temperature for cowpea seeds observed is somewhat higher than cereal grain starches gelatinization temperatures (Joye 2019; Hoover *et al*., 2010) and hence cooking at high temperature than cereal grains are required for digestibility. The relatively high gelatinization temperature in Tswana is most probably a reflection of limited water uptake for swelling. The three cowpea varieties significantly differed from each other on their viscosity developed when heated at their Tm, being superior for Blackeye and poor for Tswana (Fig 2) which is influenced by water uptake, seed sizes and available carbohydrate (mostly starch) contents being high for blackeye and low for Tswana. This shows, the water-uptake, swelling and thickening ability of flour starches from Tswana is limited where thick and stiff type of food products are desired to be processed as compared to Blackeye and ER7 flours.

Cowpeas sensory evaluation

The sensory evaluation for the three cooked cowpeas varieties evaluated on 7-point hedonic scale (1= extremely dislike to 7= extremely like) showed that the varieties had no significant difference (p>0.05) in the acceptability of aroma, color, texture, taste and overall liking (Table 4). The acceptability of the sensory attributes of the cooked cowpea seeds ranged from like slightly to like moderately. This implies that aroma, color, texture, taste and overall acceptability of the cooked cowpea did not influence the consumer's choice toward cowpeas varieties. Consumers have slightly or moderately liked all the cooked cowpea seeds.

CONCLUSION

The physical properties and cooking time of Tswana, Black-eye and ER 7 cowpea seeds studied were significantly (p<0.05) different among the varieties except for seed width. Large seeds size and HSW was observed in ER7 and lowest was for the Tswana. The flour starch granules gelatinization temperatures were ranged: To (71.3 to 73.7°C) and Tm (83.0 to 84.7°C) with insignificantly difference (p>0.05) in their To but varied in their Tm and viscosity development at their Tm, showing the degree of flour starch granules swelling, expansion and thickening for the three varieties are different. The Tswana variety showed low in its seed size, HSW, water hydration capacity, long cooking time and flour starches viscosity development at Tm. The shorter cooking time, large seed size and comparatively higher protein content of Blackeye cowpea would be more acceptable since high protein content of shorter cooking time and large seed sizes are beneficial for consumer market. The three cooked cowpea seeds sensory acceptability were evaluated from like slightly to like moderately with no significant difference (p>0.05) in their seeds cooked aroma, color, texture, taste and overall acceptability. Further studies on some parameters not considered in this study such as digestibility, mineral contents and antinutritional factors on other cowpea seed varieties grown in Botswana on the effects of different food processing conditions are recommended for future studies.

ACKNOWLEDGEMENT

The Food Science and Technology Department Technicians for supporting the 1st author while conducted the experiment and Botswana Agricultural Marketing Board

(BAMB) in Gaborone for the three cowpea seed varieties; Research Technology Development and Transfer Committee of BUAN for covering the publication cost are acknowledged in this work.

Conflict of interest

All authors declare that they have no conflict of interest.

REFERENCES

Aboagye, D., Darko, J.O. and Banadda, N. (2017). Comparative study of hermetic and non hermetic storage on quality of cowpea in Ghana. Chemical and Biological Technologies in Agriculture. 4(10): 1-6. doi.10.1186/s40538-017-0091-y.

Adebooye, O.C. and Singh, V. (2008). Physico-chemical properties of the flours and starches of two cowpea varieties (*Vigna unguiculata* (L.) Walp. Innovative Food Science and Emerging Technologies. 9: 92-100. doi.org/10.1016/j.ifset.2007.06.003.

Affrifah, N.S., Phillips, R.D. and Saalia, F.K. (2021a). Cowpeas: nutritional profile, processing methods and products-A review. Legume Science. 4: e131. doi.org/10.1002/leg3.131.

Affrifah, N.S., Chinnan, M.S., Saalia, F.K. and Phillips, R.D. (2021b). Hydrothermal treatments affect the development of the hard to-cook defect in cowpeas. Legume Science. 4: e126. doi.org/10.1002/leg3.126.

Antova, G.A., Stoilova, T.D. and Ivanova, M.M. (2014). Proximate and lipid composition of cowpea (*Vigna unguiculata* L.) cultivated in Bulgaria. Journal of Food composition and Analysis. 33:146-152, doi.org/10.1016/j.jfca.2013.12.005.

AOAC (Association of Official Analytical Chemists). (1998). Official Methods of Analysis of AOAC International, 16th Edition, Gaithersburg, MD, USA Method Nos: 925.10, 920.87, 920.39, 962.09 and 923.03.

Awika, J.M. and K.G. Duodu, K.D. (2017). Bioactive polyphenols and peptides in cowpea (*Vigna unguiculata*) and their health promoting properties: A review. Journal of Functional Foods. 38 (Part B): 686-697. doi.org/10.1016/jff.2016.12.002.

BeMiller, J. and Whistler, R. (2009). Starch: Chemistry and Technology, 3rd ed., Academic Press, Burlington, MA, USA.

Brabender® GmbH and Co. KG. (2005). Brabender Measurement and Control Systems:Instruction Manual for Brabender Amylograph®E for Windows®, Ident No. 2200 and Amylograph Correlation Program for Windows®, Ident No. 72202, Version 4.0 and further, Brabender OHG, Duisburg, Germany.

Carvalho, A.F.U., de Sousa, N.M., Farias, D.F., da Rocha-Bezerra, L.C.B., da Silva, R.M.P., Viana, M.P., Gouveia, S.T., Sampaio, S.S., de Sousa, M.B., de Lima, G.P.G., de Morais, S.M. Barros, C.C. and Filho, F.R.F. (2012). Nutritional ranking of 30 Brazilian genotypes of cowpeas including determination of antioxidant capacity and vitamins. Journal of Food Composition and Analysis. 26: 81-88. doi.org/10.1016/j.jfca.2012.01.005.

Coffigniez, F., Briffaz, A., Mestres, C., Akissoé, L., Bohuon, P. and Maâtaoui, M.E. (2019). Impact of soaking process on the microstructure of cowpea seeds in relation to solid losses and water absorption. Food Research International. 119: 268-275. doi.org/10.1016/j.foodres.2019.02.010.

DAR (Department of Agricultural Research). (1983). Description of cowpea variety ER7.Crops Research Bulletin No.2. Ministry of Agriculture, Gaborone, Botswana.

Demooy, B.E. and Demooy, C.J. (1989). Effects of leaf-harvesting practices on yield and yield components of ER-7 cowpea [*Vigna unguiculata* (L.) Walp.] in semi-arid Botswana. Field Crops Research. 22: 27-31. doi.org/10.1016/0378-4290(89)90086-5.

Demooy, B.E. and Demooy, C.J. (1990). Evaluation of cooking time and quality of seven diverse cowpea [*Vigna unguiculata* (L.) Walp.] varieties. International Journal of Food Science and Technology. 25(2): 209-212. doi.org/10.1111/j.1365-2621.1990.tb01076.x.

Egbadzor, K.F., Yeboah, M., Danquah, E.Y., Ofori, K. and Offei, S.K. (2013). Identification of SNP markers associated with seed size in cowpea [*Vigna unguiculata* (L) Walp. International Journal of Plant Breeding and Genetics. 7(2): 115-123. doi.org/10.1186/s12863-020-00914-7.

Gonçalves, A., Goufo, P., Barros, A., Domínguez-Perles, R., Trindade, H., Rosa, E.A.S., Ferreira, L. and Rodrigues, M. (2016). Cowpea [*Vigna unguiculata* (L.) Walp], A Renewed multipurpose crop for a more sustainable agri-food system: Nutritional advantages and constraints. Journal of the Science of Food and Agriculture. 96: 2941-2951. doi:10.1002/jsfa.7644.

Hamid, S., Muzaffar, S., Wani, I.A., Masoodi, F.A. and 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: 127-134. dx.doi.org/10.1016/j.jssas.2014.08.002.

Henshaw, F.O. (2008). Varietal differences in physical characteristics and proximate composition of cowpea (*Vigna unguiculata*). World Journal of Agricultural Sciences. 4(3): 302-306.

Hoover, R., Hughes, T., Chung, H.J. and Liu, Q. (2010). Composition, molecular structure, properties and modification of pulse starches: A review. Food Research International. 43: 399-413. doi.org/10.1016/j.foodres.2009.09.001.

IBM Corporation. (2017). SPSS® Statistics Version 25 Software, NY 10504-1785, USA.

Jayathilake, C., Visvanathan, R., Deen, A., Bangamuwage, R., Jayawardana, B.C., Nammi, S and Liyanage, R. (2018). Cowpea: An overview on its nutritional facts and health benefits. Journal of the Science of Food and Agriculture. 98(13): 4793-4806. doi.org/10.1002/jsfa.9074.

Joye, I.J. (2019). Starch. In: L. Melton, F. Shahidi, P. Varelis (Eds.) Encyclopedia of Food Chemistry, Elsevier Ltd., Oxford, UK, Vol. 1: 256-264. doi.org/10.1016/B978-0-08-100596-5.21586-2.

Kalpanadevi, V. and Mohan, V.R. (2013). Effect of processing on antinutrients and *in vitro* protein digestibility of the underutilized legume *Vigna unguiculata* (L.) Walp subsp. *Onguiculata*. LWT - Food Science and Technology. 51: 455-461. doi.org/10.1016/j.lwt.2012.09.030.

Kim, Y-Y., Woo, K.S. and Chung, H-J. (2018). Starch characteristics of cowpea and mungbean cultivars grown in Korea. Food Chemistry. 263: 104-111. doi.org/10.1016/j.foodchem.2018.04.114.

Kinyanjui, P.K., Njoroge, D.M., Makokha, A.O., Christiaens, S., Ndaka, D.S. and Hendrickx, M. (2015). Hydration properties and texture fingerprints of easy-and hard-to-cook bean varieties. Food Science and Nutrition. 3(1): 39-47. doi.org/10.1002/fsn3.188.

Lawless, H.T. and Heymann, H. (2010). Sensory Evaluation of Food: Principles and Practices, 2nd ed., Springer, London, UK.

Li, Y.O. and Komarek, A.R. (2017). Review: Dietary Fiber Basics: health, nutrition, analysis and applications. Food Quality and Safety. 1: 47-59. doi:10.1093/fqs/fyx007.

Madodé, Y.E., Nout, M.J.R., Bakker, E.J., Linnemann, A.R., Hounhouigan, D.J. and van Boekel M.A.J.S. (2013). Enhancing the digestibility of cowpea (*Vigna unguiculata*) by traditional processing and fermentation. LWT - Food Science and Technology. 54: 186-193. doi.org/10.1016/j.lwt.2013.04.010.

Mashungwa, G.N., Moroke, T.S., Kgosiesele, E. and Kashe, K. (2019). Grain legume production and their potential for sustainable agriculture in Botswana between 2008 and 2015 - A review. Botswana Journal of Agriculture and Applied Sciences. 3 (Issue 1-Special): 80-90. doi.org/10.37106/bojaas.2019.11

Mendes, V., Niforou, A., Kasdagli, M.I., Ververis, E. and Naska, A. (2023). Intake of legumes and cardiovascular disease: A systematic review and dose response meta- analysis. Nutrition, Metabolism and Cardiovascular Diseases. 33: 22-37. doi.org/10.1016/j.numecd.2022.10.006.

Monro, J. and Burlingame, B. (1996). Carbohydrates and related food compounds: IN FOODS tagnames, meanings and uses. Journal of Food Composition and Analysis. 9: 100-118. doi.org/10.1006/jfca.1996.0018.

Narayana, M., M. Angamuthu, M. (2021). Chapter 11. Cowpea. In: The Beans and the Peas: From Orphan to Mainstream Crops, [Pratap, A. and Gupta, A.S. (eds)], Woodhead Publishing is an imprint of Elsevier, United Kingdom, 241-272. doi.org/10.1016/B978-0-12-821450-3.00007-X.

Pramiu, P.V. Rizzi, R.L. do Prado, N.V. Coelho, S.R.M. Bassinello, P.Z. (2015). Numerical modeling of chickpea (*Cicer arietinum*) hydration: the effects of temperature and low pressure. Journal of Food Engineering. 165: 112-123. doi.org/10.1016/j.jfoodeng.2015.05.020.

Santos, C.A.F. and Boiteux, L.S. (2013). Breeding biofortified cowpea lines for semi-arid tropical areas by combining higher seed protein and mineral levels. Genetics and Molecular Research. 12(4): 6782–6789. doi.10.4238/2013.

Silva, M.G.C., Silva, G.N., Sousa, A.H., Freitas, R.S., Silva, M.S.G. and Abreu, A.O. (2018). Hermetic storage as an alternative for controlling *Callosobruchus maculatus* (*Coleoptera*: *Chrysomelidae*) and preserving the quality of cowpeas. Journal of Stored Products Research. 78: 27-31. doi.org/10.1016/j.jspr.2018.05.010.

Sobukola, O.P. and Abayomi, H.T. (2011). Physical properties and rehydration characteristics of different varieties of maize (*Zea mays L.*) and cowpea [*Vigna unguiculata* (L.) Walp] seeds. Journal of Food Processing and Preservation. 35(3): 299-307. doi:10.1111/j.1745-4549.2009.00455.x.

Sood, M., Malhotra, S.R. and Sood, B.C. (2002). Effect of processing and cooking on proximate composition of chickpea (*Cicer arietinum*) varieties. Journal of Food Science and Technology. 39: 69-71.

Sombié, P.A.E.D., Sama, H., Barro, A., Hilou, A. and Kiendrébéogo, M. (2021). The effect of seed size on phytochemical composition in cowpea lines [*Vigna unguiculata* (L.) Walp.] from Burkina Faso. Agricultural Sciences. 12. 1462-1472. doi.org/10.4236/as.2021.1212093.

Teka, T.A., Retta, N., Bultosa, G., Udenigwe, C., Shumoy, H. and Raes, K. (2020). Phytochemical profiles and antioxidant capacity of improved cowpea varieties and landraces grown in Ethiopia. Food Bioscience. 37: 1-10. doi: 10.1016/j.fbio.2020.100732.

Toan Do, D. and Singh, J. (2019). Legume Microstructure. In: Encyclopedia of Food Chemistry, [L. Melton, F. Shahidi, P. Varelis (Eds.)] Elsevier Ltd., Oxford, UK, Vol. 3: 15-21. doi. 10.1016/B978-0-08-100596-5.21683-1.

Tresina, P.S and Mohan, V.R. (2012). Physico-chemical and antinutritional attributes of gamma irradiated *Vigna unguiculata* (L.) Walp. subsp. *unguiculata* seeds. International Food Research Journal. 19(2): 639-646.

USDA (United States Department of Agriculture). (2018). National Nutrient Database for Standard Reference. SR28, Washington DC, USA.