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DETERMINATION OF PHYSICAL, CHEMICAL, FUNCTIONAL AND MECHANICAL PROPERTIES OF FIVE NEW CULTIVARS OF SOYBEAN SEEDS

[*1]Ogunbisi M. A., [2]Odetunde M.T., [2]Olayiwola E.O., and [2]Ogundipe O. O.

[1]*Department of Chemical Sciences, Yaba College of Technology, Lagos, Nigeria*
[2]*Department of Food Technology, Yaba College of Technology, Lagos, Nigeria*
***Corresponding Authors:** mercy.ogunbisi@yabatech.edu.ng; +2348023631389

ABSTRACT

Soybean is an economically important bean, because it is a rich source of various vitamins, minerals, and beneficial plant compounds. The knowledge of the physical, chemical, functional and mechanical properties of soybean is important for postharvest operations. Five different cultivars of soybean seeds (TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1988-5F and TGX 1987-62F) were evaluated using standard procedures. The results of the physical parameters are: Mean length (6.13 – 7.57mm), width (5.45 – 6.41mm) and thickness (4.56 –5.26mm). Other calculated physical parameters such as arithmetic mean diameter (5.38 –6.42mm), geometric mean diameter (5.33 – 5.94 mm), sphericity (0.83 – 0.88), aspect ratio (0.82 – 0.90), surface area (80.99 – 111.96 mm^2), volume (13.48 – 18.66 mm^3) were significantly different from one another. Also, true density (0.25 – 0.26), kernel density (1.04 – 1.26 g/cm^3), bulk density (0.76 – 0.8039 g/cm^3), porosity (22.85 – 39.2), angle of repose (13.67 – 16), 100 seed kernel weight (9.11 – 16.54 g), elongation ratio (1.41 – 1.57 mm) varied with cultivar. The functional properties (Hydration capacity, Hydration index, swelling capacity, Swelling Index, Foam capacity and stability, Oil absorption capacity, Water absorption capacity) were significantly ($P \leq 0.05$) different in between treatments in this study. Significant ($P \leq 0.05$) differences were observed in mean scores of proximate compositions of the soybean cultivars. The results of this study is useful in predicting potential uses of these five new cultivars of Soybean grains in food processing preservation, food handling, storage and distribution.

KEYWORDS: Physical, Chemical, Mechanical, Soybean

INTRODUCTION

Soybean is a leguminous plant usually found in tropical, subtropical, and temperate climates. It is believed that it might have been introduced to Africa in the 19th century by Chinese traders along the east coast of Africa (IITA, 2009). Proximate composition of soybean is approximately 40% protein, 35% total carbohydrate and 20% cholesterol-free oil, 1.7% potassium, 0.3% for magnesium, 110ppm iron, 50ppm zinc and 20ppm copper (Manuwa, 2011). Improved varieties of Soybean were developed in Nigeria at the International Institute of Tropical Agriculture, Ibadan. Such major improvements include but are not limited to increase grain yield by about 20%, improve resistance to pod shattering and to maintain the level of all other traits constant. (Manuwa, 2011). The soybean plant has lately been increasingly important for resource in agriculture, because it is one of the main food sources in human and animal nutrition. It is reputed to have, high quality protein and is free of cholesterol and saturated fatty acids. In the food industry it is used primarily for manufacture of soybean protein products (Kibar and Ozturk, 2008). Despite the importance of soybean, there is not much information about its physical, chemical and mechanical properties hence, this study is aimed to determine the physical, chemical, mechanical and functional properties of five new cultivars of soybeans (TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1988-5F and TGX 1987-62F) developed by International Institute of Tropical Agriculture (I.I.T.A.)

MATERIALS AND METHODS

Preparation of soybean seeds

The soybean seed cultivars obtained from IITA were cleaned manually to remove unwanted materials, damaged and unhealthy seeds. The initial moisture content of the soybean seeds was determined using the oven-dry method as described by (AOAC, 2005) at 105 ^{0}C for 6 hrs in the oven.

One Hundred Mass Seed Weight

One hundred seed weight was determined by weighing 100 randomly selected raw seeds of each variety as recommended by AOAC, 2000.

Determination of Physical Properties of Soybean

The following physical characteristics: Length, width and thickness of randomly selected soybean seeds were determined by measuring the three major perpendicular dimensions with the aid of a digital Vernier calliper (12″ Digital Calliper, Carrera Precision, Nanjing Sulang Co., Ltd., Jiangsu, China) to an accuracy of 0.01 mm (Falade & Adebiyi, 2015).

Arithmetic Mean Diameter

The arithmetic mean diameter (D_a), was calculated using the equation below (Ozturk *et al*., 2009).

$$D_a = \frac{(L + W + T)}{3}$$

Geometric Mean Diameter

The geometric mean diameter (D_g) of the soybean was calculated by using the following relationship (Ozturk *et al*., 2009).

$$D_g = LWT^{1/3}$$

Where, L is the length; W is the width and T is the thickness in mm.

Sphericity

Samples were randomly chosen from each soybean cultivar. The experimental design to be used is randomized complete block design (RCBD). The sphericity (Φ) was calculated using the formula (Nwakonobi and Idike, 2003).

$$\Phi = (LWT)^{1/3}/L$$

Where, L is the length; W is the width and T is the thickness in mm.

True Density

The toluene displacement method was used to determine, the true density of the soybean. Soybean sample (about 2.5 g) was submerged in 100 ml of toluene in a measuring cylinder having an accuracy of 0.1 mL, the increase in volume due to sample was noted as true volume of sample which was used to determine the true density of the sample (Karababa, 2005).

Bulk Density

The bulk density measures the ratio of the mass sample of kernels to its total volume. It can be determined by filing a 1000 ml container with kernels from a height of about 15 cm, striking the top level and then weighing the contents. (Karababa, 2005).

Kernel Density

The kernel density is a water displacement method. It depicts the ratio of mass of the sample to its kernel volume. Five hundred millilitres of water were poured into a 1000 ml graduated measuring cylinder and 25 g seeds immersed in the water. The duration of the experiment is very so as not to allow the skin of the kernel to absorb daily, the seeds were not coated to prevent moisture adsorption. The amount of displaced water was recorded from the graduated scale of the cylinder. The ratio of weight of seeds to the volume of displaced water gave the kernel density (Karababa, 2005).

Porosity

Porosity (έ) helps us determine the fraction of the space in the bulk grain not occupied by the grain. The porosity of bulk seed was computed from the values of kernel density and bulk density using the relationship given by:

$$\acute{\varepsilon} = \rho_k - \rho_b \, x \, \frac{100}{\rho_k}$$

Where ρ_b is the bulk density and ρ_k is the kernel density (Karababa, 2005)

Angle of Repose

The angle of repose is the characteristics of the bulk material which indicates the cohesion among the individual grains, the higher the cohesion, the higher the angle of repose. The angle of repose is the angle from the horizontal at which the material will rest in a pile. This was determined by using an open-ended cylinder of 15 cm diameter and 30 cm height. The cylinder was placed at the centre of circular plate having a diameter of 70 cm and filled with soybean grains. The cylinder was raised slowly until it forms a cone on the circular plate. The height of the cone was recorded. The angle of repose, θ was calculated by using the following formula:

$$\theta = \tan^{-1}\frac{2h}{d}$$

Where, θ is the angle of repose; h is the height of pile and d is the diameter of cone.

Aspect ratio (Ra)

This was calculated by using the formula:

$$R_a = \frac{width}{length}$$ *(Kibar and Ozturk, 2008).*

Surface Area

The surface area as in mm^2 of soybean grains was determined by analogy with a sphere of same geometric mean diameter, using the following relationship;

$$S = \frac{\pi BL^2}{2L-B}$$ *(Kibar and Ozturk, 2008).*

Volume

The volume of the soybean sample depending on the shape of the grains was determined using Eqns. (3), (4), (5) as described by Jain and Bal (1997) as found in Kibar and Ozturk (2008).

$$V = \frac{\pi BL^2}{6(2L-B)}$$

Elongation Ratio

The initial length of 10 soybean seed of each of the five cultivars would be measured with a digital veneer calliper (12″ Digital Calliper, Carrera Precision) with an accuracy of ±0.01 mm. Seeds would be cooked in excess water (200 mL) in a 1000 mL beaker placed on an electric heater. Cooked, samples would be removed and drained dapped on tissue paper to remove excess water, then final length would be measured to determine the increase in length. Elongation ratio would then be calculated, (Falade & Adebiyi, 2015).

$$Elongation\ ratio = \frac{Length\ of\ cooked\ beans}{Length\ of\ raw\ beans}$$

Determination of Proximate Properties of Soybean

Moisture Content

Moisture content determination was carried out using the air oven method. Crucibles were washed and dried in an oven. They were allowed to cool in the desiccator and weight was noted. A known weight (3g) of samples were then transferred into the crucibles and dried at a temperature between 103 and 105^0C. The dry samples were cooled in a desiccator and the weight noted. They were later returned to the oven and the process continued until constant weights were obtained (Kashaninejad *et al*., 2003; Karababa, 2005).

$$\%\ Moisture\ conten = \frac{\text{Weight Loss X 100}}{Weight\ of\ sample}$$

Determination of Ash content

A known weight (1.5 g) of finely ground sample was weighed into clean, dried previously weighed crucible with lid (W_1). The sample was ignited over a low flame to char the organic matter with lid removed. The crucible was then placed in muffle furnace at 600 ^{0}C for 6 hours until the ashing was completed. It was then transferred directly to desiccators, cooled and weighed immediately (W_2) (Eden & Rumambarsari, 2020).

$$Percentage\ Ash = \frac{(W_2 - W_1)\ \text{x}\ 100}{Weight\ of\ Sample}$$

Determination of Crude Fat

The soxhlet extraction method (AOAC, 2005) was used. This method could only give the approximate fat content in a sample because all the substances soluble in chosen solvent (Petroleum ether, 40° C – 60 ^{0}C boiling range) were extracted from the sample.

A known weight (2 g) of sample was weighed into a weighed filter paper and folded neatly. This was put inside pre-weighed thimble (W_1).

The thimble with the sample (W_2) was inserted into the soxhlet apparatus and extraction under reflux was carried out with petroleum ether (40 ^{0}C – 60 ^{0}C) boiling range for 6 hours. At the end of extraction, the thimble was dried in the oven for about 30 minutes at 100 ^{0}C to evaporate off the solvent and thimble was cooled in a desiccator and later weighed (W_3).

The fat extracted from a given quantity of sample was then calculated:

$$\%\ \boldsymbol{Fat\ (w/w)} = \frac{\boldsymbol{Loss\ in\ Weight\ of\ sample\ x\ 100}}{\boldsymbol{Original\ Weight\ of\ sample}} = \frac{\boldsymbol{(W_2 - W_3)\ x\ 100}}{\boldsymbol{(W_2 - W_1)}}$$

Protein Determination

The crude protein content was determined using micro Kjeldahl method as described in AOAC (2005). About 0.2077g of sample was weighed into a long necked Kjeldahl flask. One tablet of Kjeldahl catalyst was added to the sample in the flask with 25cm^3 of conc. H_2SO_4. The flask was swirled, gently clamped in an inclined position and heated electricity in a fume cupboard. The heating continue until a clear solution was obtained. The clear solution was cooled, poured into a 100cm^3 volumetric flask and made up to mark with distilled water 10ml of the resulting mixture was measured into the distillation set through the funnel. 5 cm^3 of boric acid was pipetted into a 100 cm^3 conical flask and placed at the receiving end of the distillatory. The conical flask was placed such that the delivery tube dipped completely into the boric acid inside the flask. 40% NaOH was used to liberated ammonia out of the digest under alkaline condition during the distillation 2 drops of methyl orange were always added to the round bottom flask containing the digested sample before 40% NaOH was added. As soon as the contents became alkaline, the red colour changed to yellow showing NaOH to be in excess. Steam was then generated into the distillation set using a steam chest. The liberated ammonia was trapped in the boric acid solution and about 50 cm^3 of the solution collected into a conical flask. The solution in the flask was titrated against 0.1M HC1 until the first permanent colour change was observed.

A blank sample was through the sample procedure and the titre value for the blank was used to correct the titre for samples.

$$\%\ \boldsymbol{N} = \frac{\boldsymbol{Molarity\ of\ HC1\ x\ Sample\ titre - Blank\ titre)\ x\ 0.014\ x\ DF\ x\ 100}}{\textbf{Weight of sample used}}$$

% N was converted to the percentage crude protein by multiplying by 6.25

Crude Fibre

Two hundred millilitre (200ml) freshly prepared 1.25 % H_2SO_4 were added to 3g of the residue obtained from fat extraction and this was boiled for was 30 minutes.

The mixture was filtered and residue washed until it was free from acid. The residue was transferred quantitatively into a digestion flask, 1.25% NaOH was added and allowed to boil for 30 minutes. The mixture was filtered and residue washed free of alkali.

The residue was then washed with methylated spirit, thrice with petroleum ether using small quantities. It was allowed to properly drain and the residue was transferred to a silica dish (previously ignited at 600 ^{0}C and cooled).
The dish and its content were dried to constant weight at 105 ^{0}C.

The organic matter of the residue was burnt by igniting for 30 minutes in a muffle furnace at 600 ^{0}C. The residue was cooled and weighed. The loss on ignition was reported as crude Fibre (AOAC, 2005).

Carbohydrate
The carbohydrate content was calculated by difference.

$$\%\ \boldsymbol{CHO = 100 -}\ (\boldsymbol{Sum\ of\ the\ percentages\ of\ moisture, ash, fat, protein\ and\ crude\ fibre})$$

DETERMINATION OF MECHANICAL PROPERTIES OF SOYBEAN
Digital Handheld hardness tester by Electrolab (Model EH-01), made in Mumbai, India. The guard cover was slide towards the knob end to open it was ensured that the seed touched the load cell and then the axial centre of the unit closed by sliding the safety guard cover again back to the initial position to close Then the knob was turned during the test and the plunger was driven (Bamgboye and Adebayo, 2012) forward which gave a gentle movement and pressed the seed against the load cell end jaw .the process continued until the seed was fractured the rupture force was registered by the unit the readings were taken in KgF.

DETERMINATION OF FUNCTIONAL PROPERTIES OF SOYBEAN
Hydration Capacity
Twenty grams of cotyledons in triplicate were enumerated and transferred to a measuring jar containing 100mL distilled water and it was left for 24h at room temperature (29 + 2 ^{0}C). Later the water was drained; cotyledons were blotted to remove adhered water and weighed.

$$\boldsymbol{Hydration\ capacity}\left(\frac{\boldsymbol{g}}{\boldsymbol{cotyledon}}\right) = \frac{\boldsymbol{(W_2 - W_1)}}{\boldsymbol{N}}$$

Where:
W_2 is weight of cotyledon after soaking and
W_1 is weight of cotyledon before soaking and
N is number of cotyledon (Tiwari *et al.*, 2008).

Hydration Index
It is the ratio of hydration per seed/cotyledon to that of weight of one seed or cotyledon.

$$\boldsymbol{Hydration\ index} = \frac{\boldsymbol{Hydration\ capacity\ of\ cotyledon}}{\boldsymbol{Weight\ of\ one\ cotyledon}}$$ (Tiwari *et al.*, 2008)

Swelling Capacity
Twenty grams of cotyledons were enumerated in triplicate; its volume was determined and soaked overnight in distilled water. Volume of the soaked cotyledon was noted in a graduated cylinder.

$$\boldsymbol{Swelling\ capacity}\left(\frac{\boldsymbol{ml}}{\boldsymbol{cotyledon}}\right) = \frac{\boldsymbol{V_2 - V_1}}{\boldsymbol{N}}$$

Where V_2 is the volume of cotyledon after soaking and V_1 is the volume of cotyledon before soaking; N is number of cotyledon (AOAC, 2005).

Swelling Index
It is the ratio of swelling capacity of cotyledon to that of volume of one cotyledon (AOAC, 2005).

$$\textbf{Swelling index} = \frac{\textbf{Swelling capacity}}{\textbf{Weight of one cotyledon}}$$

Foam Stability
One gram of soybean flour was whipped with 100 ml distilled water for 5 min in a Kenwood blender at 500 rpm and poured into a 250ml graduated cylinder. The volume of foam at 30 sec after whipping was recorded as the foam capacity and the volume of the foam after 60 min was recorded as the stability for the duration of measurement (Appiah *et al*., 2011).

Bulk density
Using the procedure described by (Appiah *et al*., 2011), 50 g of soybean flour was put into a 100 ml measuring cylinder and tapped to a constant volume and the bulk density (gcm^3) was calculated using the formula:

$$\textbf{Bulk density} = \frac{\textbf{weight of flour } (g)}{\textbf{Flour volume } (cm^3)}$$

Water and oil absorption capacities
To one gram of soybean flour, 10 ml distilled water or refined palm oil in a pre-weighed 20 ml centrifuge tube. The slurry was agitated for 2 min, allowed to stand at 28°C for 30 min and then centrifuged at 500 rpm for 20 min. The clear supernatant was decanted and discarded. The adhering drops of water or oil in the centrifuge tube was removed with cotton wool and the tube was weighed, the weight of water or oil absorbed by 1 g of flour or protein was calculated and expressed as water or fat absorption capacity (Appiah *et al*., 2011).

Length (mm)
Length mean scores values for the length obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 6.13mm, 7.62mm, 6.77mm, 6.58mm, 7.57mm respectively with cultivar TGX 1987-10F having the minimum value and cultivar TGX 1989-19F having the maximum value. It was observed that there was a significant difference ($P< 0.05$) in all the cultivars.

DATA ANALYSIS
Samples analysis were carried out in triplicate and data analysis was done using The Statistical Package for Social Sciences (SPSS) version 21.0. The level of statistical significant difference was taken at $P<0.05$.

RESULTS AND DISCUSSION

Physical Properties Soybean Cultivars
The physical dimensions and also the mechanical properties of any grain are important in the design, fabrication and utilization of equipment especially for pre and post-harvesting technology. They are also important in a lot of food related unit operations such as transporting, storage, cleaning, separation, sorting, sizing, packaging and processing into different food products (Fathollahzadeh *et al*., 2008).
Tables 1 and 2 show the physical properties of the five varieties of soybean cultivars that were analysed which are TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1988-5F, TGX 1987-62F. The results of the analyses are given in tables and discussed below.

Table 1: Physical properties of soybean cultivars

Sample Code	Length (mm)	Width (mm)	Thickness (mm)	Arithmetic Mean Diameter (mm)	Geometric Mean Diameter (mm)	Sphericity (%)	Aspect ratio	Surface Area $(mm)^2$
TGX1987-10F	6.13±0[a]	5.45±0[a]	4.56±0[a]	5.38±0.00[a]	5.33±0.00[a]	0.86±0.00[b]	0.90±0.00[d]	80.91±0.06[a]
TGX1989-19F	7.62±0.01[e]	6.25±0.01[d]	5.37±0.01[e]	6.42±0.00[d]	6.33±0.00[e]	0.83±0.00[a]	0.82±0.00[a]	111.98±0.10[d]
TGX1835-10E	6.77±0[c]	6.09±0.01[c]	5.11±0.01[c]	5.98±0.01[c]	5.94±0.01[c]	0.87±0.00[c]	0.89±0.00[e]	100.83±0.26[c]
TGX1987-62F	6.58±0[b]	5.73±0[b]	5±0[b]	5.77±0.01[b]	5.73±0.00[b]	0.88±0.00[c]	0.87±0.00[c]	93.31±0.06[b]
TGX1988-5F	7.57±0[d]	6.41±0[e]	5.26±0[d]	6.41±0.00[d]	6.32±0.00[d]	0.83±0.00[a]	0.84±0.00[b]	111.96±0.06[d]

Values are means ± standard deviation. Means in a column with the same superscript letters are not significantly different (P≥0.05)

Table 2. Other Physical properties of soybean cultivars

Sample Code	Volume $(mm)^3$	True density (g/cm^3)	Kernel density (g/cm^3)	Bulk Density (g/cm^3)	Porosity (%)	Angle of Repose (^{0})	100 Seed Kernel Weight(g)	Elongation Ratio (mm)
TGX1987-10F	13.48±0.01[a]	0.25±0[a]	1.04±0[a]	0.8039+0[a]	22.85±0[a]	15±1[c]	9.11±0.04[a]	1.57±0[a]
TGX 1989-19F	18.66±0.01[d]	0.26±0[a]	1.26±0[a]	0.7900+0[a]	36.8±0[a]	15±1[d]	16.54±0.24[d]	1.42±0[a]
TGX 1835-10E	16.80±0.04[c]	0.25±0[a]	1.04±0[a]	0.7810+0[a]	25.05±0[a]	13.67±0.57[a]	13.40±0.12[c]	1.51±0[a]
TGX 1987-62F	15.55±0.01[b]	0.25±0[a]	1.25±0[a]	0.7772+0[a]	37.82±0[a]	13.67±1.15[b]	11.53±0.09[b]	1.41±0[a]
TGX 1988-5F	18.65±0.01[d]	0.25±0[a]	1.25±0[a]	0.7600+0[a]	39.2±0[a]	16±1[e]	16.54±0.03[d]	1.51±0[a]

Values are means± standard deviation. Means in a column with the same superscript letters are not significantly different (P≥0.05).

Width (mm)

Width mean scores values for the width obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study ranged from 5.45mm – 6.41mm with cultivar TGX 1987-10F having the minimum value and cultivar TGX 1988-5F having the maximum value. It was observed that there was a significant difference (P≤ 0.05) in width for all the cultivars of Soybeans used in this study.

Thickness (mm)

Thickness mean scores values for the thickness obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 4.56mm, 5.37mm, 5.11mm, 5.0mm, 5.26mm respectively. Cultivar TGX 1987-10F had the least value and cultivar TGX 1989-19F had the highest value. It was observed that there

was a significant difference (P≤ 0.05) in all the cultivars of Soybeans in this study.

Arithmetic Mean Diameter (mm)

Mean scores for arithmetic mean diameter values for the arithmetic mean diameter obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 5.38mm, 6.42mm, 5.98mm, 5.77mm, 6.41mm respectively. This is a function of the length, width and thickness of the grains (mm). The results obtained ranged between 5.38 – 6.42mm with TGX 1987-10F having the minimum value and TGX 1989-19F having the maximum value. No significant (P> 0.05) difference was observed between TGX 1989-19F and TGX 1988-5F; however, there was a significant difference, between TGX 1987-10F, TGX 1835-10E and TGX 1987-62F.

Geometric Mean Diameter (mm)

Mean score for geometric mean values for the geometric mean diameter obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 5.33mm, 6.3mm, 5.94mm, 5.73mm, 6.32mm respectively. The geometric mean diameter like the arithmetic mean diameter is also a function of the length, width and thickness of the grain and it was calculated by using a standard equation as described in the methodology. The geometric mean of the axial dimensions is important in determining the projected area of a particle moving in the turbulent or near-turbulent air stream. Projected area of particles helps to predict behaviour in a flowing fluid such as air, as well as the ease of separating extraneous material from the particle during cleaning by pneumatic means (Asoiro *et al*., 2017). The results obtained ranged between 5.33mm – 6.33mm, with cultivar TGX 1987-10F having the minimum value and cultivar TGX 1989-19F, having the maximum value. A significant difference (P< 0.05) was observed in the cultivars.

Sphericity (%)

Sphericity mean scores values for sphericity obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 0.86%, 0.83%, 0.87%, 0.88%, 0.83% respectively. The sphericity of the soybean cultivars is related to the geometry. It refers to the shape of the seeds and pre - determines how a seed will roll on a surface. The flat shape of the seeds enables the seeds to slide. This property is quite important in the design of machine components, such as hoppers and dehullers for seeds. Seeds that are flat in geometry slide easier than spherical seeds, which roll on structural surfaces. The results of sphericity obtained for the five cultivars of Soybean in this study ranged from 0.83% – 0.88% with cultivar TGX 1989-19F and TGX 1988-5F having the minimum value and cultivar TGX 1987-62F having the maximum value for sphericity. No significant difference (P> 0.05) was observed between TGX 1989-19F and TGX 1988-5F and also TGX 1835-10E and TGX 1985-62F, however there was a significant difference (P< 0.05) amongst the five cultivars.

Aspect Ratio

Aspect ratio mean scores values for aspect ratio obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 0.90, 0.82, 0.89, 0.87, 0.84 respectively. The aspect ratio of the soybean cultivars is the ratio of width to the length; using the formula described by Omobuwajo *et al*. (1999), the values obtained ranged between 0.82 – 0.90 with TGX 1989-19F having the minimum value and TGX 1987-10F having the maximum value. A significant difference (P< 0.05) was observed between the five cultivars in this study.

Surface Area (mm^2)

Surface area mean scores values for surface area obtained for cultivars, TGX 1987-10F,

TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 80.91mm^2, 111.98mm^2, 100.83mm^2, 93.31mm^2, 111.96mm^2 respectively. The surface area is a function of the geometric mean diameter, while the geometric mean diameter is a function of the grain's length, width and thickness. The surface area of food and agricultural biomass affects the velocity of air streams. This is particularly useful in separation operations, especially when it is desirable to separate the product from an unwanted material in pneumatic separator or to convey seeds in pneumatic conveying (Asoiro *et al*., 2017). The values obtained for surface area ranged between 80.91mm^2 – 111.98mm^2 with TGX 1987-10F having the minimum value and TGX 1989-19F having the maximum value for surface area. A significant difference was observed among the samples however, no significant difference ($P>0.05$) was obtained between TGX 1989-19F and TGX 1988-5F.

Volume (mm^3)

Volume mean scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 13.48mm^3, 18.66mm^3, 16.80mm^3, 15.55mm^3, 18.65mm^3 respectively. Equal amount of each soybean cultivar were weighed, the difference in their volume is as a result of the differences in their shape and size. The values obtained ranged between 13.48mm^3 – 18.66mm^3 with TGX 1987-10F having the minimum value and TGX 1989-19F having the maximum value. Significant difference ($P< 0.05$) were observed among the samples, however there was no significant difference in the means of samples TGX 1989-19F and TGX 1988-5F.

True density (g/cm^3)

True density means scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 0.25g/cm^3, 0.26g/cm^3, 0.25g/cm^3, 0.25g/cm^3, 0.25g/cm^3 respectively. True density is the density of a pure substance or a composite material calculated from its components' densities considering conservation of mass and volume (Rao *et al*., 2005). The values obtained ranged between 0.25g/cm^3 – 0.26g/cm^3 with TGX 1987-10F having the minimum value and TGX 1989-19F having the maximum value. No significant difference was observed among the five cultivars in this study.

Kernel density (g/cm^3)

Kernel density mean scores values for kernel density obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 1.04g/cm^3, 1.26g/cm^3, 1.04g/cm^3, 1.25g/cm^3, 1.25g/cm^3 respectively. Kernel density refers to the density of a particle, and it includes the volume of all closed pores but not the externally connected pores. In this case, the particle is not modified structurally, as in the case of material density. The values obtained ranged between 1.04g/cm^3 – 1.26g/cm^3 with TGX 1987-10F having the minimum value and TGX 1989-19F having the maximum value, there was no significant difference ($P\geq 0.05$) between all cultivars in this study.

Bulk density (g/cm^3)

Bulk density mean scores values for bulk density obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 0.8039 g/cm^3, 0.7900 g/cm^3, 0.7810 g/cm^3, 0.7772 g/cm^3, 0.7600 g/cm^3 respectively. Bulk density of a material is the density of a material when packed or stacked in bulk.

The bulk density of packed materials has to do with the geometry, size, and surface properties of individual particles (Rao *et al*., 2005). The values obtained ranged between 0.76g/cm^3 – 0.80g/cm^3 with TGX 1988-5F having the minimum value and TGX 1987-10F having the maximum value.

No significant difference (P≥ 0.05) was however obtained between all cultivars in this study.

Porosity (%)

Porosity mean scores values for porosity obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 22.85%, 36.8%, 25.05%, 37.82%, 39.2% respectively. The Porosity of any material indicates the volume fraction of void space or air in the material. Porosity or void fraction is a measure of the void spaces or empty spaces in a material, which is between 0 to1, or as a percentage between 0 to100 percent. (Rao *et al*., 2005; Taheri *et al*., 2015), hence we can say that the porosity of the soybean grains is the volume fraction of void space or air in the grains. Also, the lower the porosity, the greater the resistance to water vapour escape during the drying process which may lead to higher power to drive the aeration fans and vice versa (Heidarbeigi *et al*., 2009). The values obtained ranged between 22.85% - 39.2% with TGX 1987-10F having the minimum value and TGX 1988-5F having the maximum value. No significant difference (P≥ 0.05) was obtained among all cultivars in this study.

Angle of repose (^{0})

Angle of repose mean scores values for angle of repose obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 15^0, 15^0, 13.67^0, 13.67^0 and 16^0 respectively. The angle of repose determines the maximum angle of a pile of grain in the horizontal plain and it is important in the filling of a flat storage facility when grain is not piled at a uniform bed depth rather is peaked (Heidarbeigi *et al*., 2009).

It is also used in design of hoppers for efficient milling in size reduction operations. This property helps to determine the minimum slope of flow in self-emptying bin and minimum slope of flow in a hopper. The results obtained ranged from 13.670 – 160, with TGX 1935-10E having the minimum and TGX 1988-5F having the maximum value. There was a significant difference in all the cultivars.

100 seed kernel weight (g)

Hundred seed kernel weight refers to the weight of hundred seeds of each cultivar as measured by a digital laboratory weighing balance. The values obtained ranged between 9.11g – 16.54g with TGX 1987-10F having the minimum value and TGX 1989-19F having the maximum value. Significant differences were observed between all cultivars, however no significant difference was observed in the means of sample TGX 1989 -19F and TGX 1988-5F.

Elongation ratio

Elongation ratio mean scores values for elongation ratio obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 1.57mm, 1.42mm, 1.51mm, 1.41mm and 1.51mm respectively. The elongation ratio of seed grains on cooking is dependent on the genetic factors as well as the degree of milling (Shamim *et al*., 2016). The values obtained ranged between 1.41 – 1.57 with TGX 1987-62F having the minimum value and TGX 1987 -10F having the maximum value, there was no significant difference between all cultivars in this study.

Table 3. Proximate composition of soybean cultivars

Parameters	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Crude Fibre (%)	Carbohydrates (%)
TGX1987-10F	8.67±0.15^{a}	39.36±0.15^{d}	19.5±0.2^{b}	4.23±0.05^{a}	1.67±0.15^{b}	26.57±0.11^{a}
TGX 1989-19F	9.13±0.15^{b}	39.67±0.15^{e}	19.57±0.15^{b}	4.33±0.15^{ab}	1.23±0.15^{a}	26.07±0.15^{a}
TGX 1835-^{10E}	9.06±0.20^{b}	37.8±0.2^{a}	18.73±0.20^{a}	4.67±0.15^{c}	1.27±0.15^{a}	28.47±0.47^{c}
TGX 1987-62F	8.6±0.2^{a}	38.8±0.1^{c}	18.63±0.15^{a}	4.77±0.15^{c}	1.6±0.1^{b}	27.6±0.36^{b}
TGX 1988-5F	8.9±0.2^{b}	38.27±0.15^{b}	19.77±0.15^{b}	4.53±0.15^{bc}	1.33±0.15^{a}	27.2±0.26^{b}

Values are means± standard deviation. Means in a column with the same superscript letters are not significantly different (P ≥0.05).

Proximate Composition of Soybean Cultivars

Table 3 shows the result for the chemical composition of the soybean seeds (TGX 1835-10E, TGX 1987-10F, TGX 1987-62F, TGX 1988-5F and TGX 1989-19F).

Moisture Content (%)

Mean scores values for moisture content obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 8.67%, 9.13%, 9.06%, 8.60% and 8.90%. The moisture content of any food is an index of its storage stability. The higher the moisture content, the more the food is predisposed to spoilage. A low level of moisture ensures good shelf life. The moisture content in seeds strongly influences the occurrence of mechanical damage, affecting elasticity and resistance in both cotyledons and the seed coat (Kuzniar *et al*., 2016). The values of mean score obtained ranged between 8.6% - 9.13% with TGX 1987-62F having the minimum value and TGX 1989 -19F having the maximum value.

No significant difference was observed between TGX 1835- 10E, TGX 1988 -5F and TGX 1989 -19F, also and there was no significant difference between the mean scores of TGX 1987 -10F and TGX 1987 - 62F.

Protein content (%)

Protein content mean scores values for protein obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 39.36%, 39.67%, 37.8%, 38.8% and 38.27% respectively. The averages protein content of the most of beans varies between 20-25% (Ogundele *et al*., 2015), In this study the protein content of soybean is about 40%. Soybean protein is low in sulphur containing amino acids, but contains sufficient lysine which is deficient in most cereals. Soybean protein is equivalent in quality to animal protein (Ogundele *et al*., 2015). The values of mean scores obtained ranged between 37.8% - 39.36% with TGX 1835 -10E having the minimum value and TGX 1987-10F having the maximum value. Significant difference ($P \leq 0.05$) was observed between cultivars of soybeans in this study. This is similar to the findings reported by Kuzniar *et al*. (2016).

Fat Content (%)

Fat content mean scores values for fat obtained for cultivars, TGX 1987-10F, TGX

1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 19.5%, 19.57%, 18.73%, 18.63% and 19.77% respectively. The values of mean score among the cultivars ranged between 18.63% - 19.77%, with TGX 1987-62F having the minimum value and TGX 1988 -5F having the maximum value, there was no significant difference between TGX 1835 -10E and TGX 1987 – 62F, and no significant difference (P<0.05) between the mean scores of TGX 1987 -10F, TGX 1989 -19F and TGX 1988 -5F. The results obtained in this study are similar to the findings of Kuzniar *et al*. (2016). Ashaye and Olusoji (2006), reported that soybean oil extracted of from its seed is fairly rich in glycerides of the unsaturated fatty acids particularly linoleic and linolenic acids with few oleic fatty acids, which do not oxidize readily because they contain natural antioxidants.

Ash content (%)

Ash content mean scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 4.23%, 4.33%, 4.67%, 4.77% and 4.53% respectively. The values obtained ranged between 4.23% - 4.77% with TGX 1987-10F having the minimum value and TGX 1987-62F having the maximum value, there was slight significant difference (P<0.05) between TGX 1987-10F and TGX 1989-19F, however there was no significant difference between TGX 1835-10E and TGX 1987-62F, and also a slight significance difference (P<0.05) in mean scores between TGX 1988-5F and (TGX 1835-10E and TGX 1987-62F).

Crude fibre (%)

Crude fibre mean scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 1.67%, 1.23%, 1.27%, 1.60%, 1.33% respectively. The values of mean scores obtained in this study ranged between 1.23% - 1.67% with TGX 1989-19F having the minimum value and TGX 1987 – 10F having the maximum value, there was no significant difference (P<0.05) in mean scores between TGX 1989-19F, TGX 1835-10E and TGX 1988-5F. No significant difference (P<0.05) was also observed in mean scores between TGX 1987-10F and TGX 1987-62F. Fibre is significant component of food and has a significant influence on metabolism in human digestion. Tresina *et al*. (2013), reported that legumes contained high fibre which slows down the release of glucose into the blood stream, consequently high legume diets are recommended for diabetic patients.

Carbohydrate content (%)

Carbohydrate content mean scores values for carbohydrate obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 26.57%, 26.07%, 28.47%, 27.60% and 27.20% respectively.

Table 4. Hardness properties of soybean cultivars

Samples	Transverse hardness KgF)	longitudinal hardness (KgF)
TGX1987-10F	13.81±1.73[a]	9.41±0.51[a]
TGX1989-19F	18.07±4.25[a]	8.68±1.18a
TGX1835-10E	18.49±9.30a	9.64±1.41a
TGX1987-62F	11.08±5.44[a]	8.03±1.24[a]
TGX 1988-5F	14.86±3.81[a]	10.36±2.12[a]

Results show mean ± standard deviation, means in a column with the same superscript letters are not significantly different (P ≤ 0.05).

Carbohydrates in soybean are low, also, soybean are very low in the glycemic index. Glycemic index helps us to determine how food affects, the rate of increase in blood sugar after a meal. Low glycemic index makes soybean of significant importance to diabetic patients.

The values of mean scores obtained, ranged between 26.07% - 28.47% with TGX 1989-19F having the minimum value and TGX 1835-10E having the maximum value. There was no significant difference ($P<0.05$) observed in mean scores between TGX 1987-10F band TGX 1989-19F, and there was no significant difference observed in mean scores between TGX 1987-62F and TGX 1988-5F, however there was significant difference ($P>0.05$) observed in mean scores among the various cultivars in this study.

Hardness Properties of Soybean Cultivars

Table 4 shows detail of hardness property of the five soybean cultivars analysed in terms of their Transverse and longitudinal section.

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Hardness is an important parameter used to design equipment for operations such as milling, threshing, and compression. It is very useful in analysing, optimization and control of the seed damage during storage and handling of grains for commercial purposes (Mohsen *et al.*, 2012).

Hardness properties of transverse section

For the transverse section, the value of mean scores ranged between 11.08 - 18.49KgF with TGX 1987-62F having the minimum value and TGX 1835-10E having the maximum value. No significant difference ($P<0.05$) was observed among the cultivars in this study.

Hardness properties of longitudinal section

For the longitudinal section, the values of mean scores for force applied ranged between 8.03KgF-10.36KgF with TGX 1987-62F having the minimum value and TGX 1988-5F having the maximum value, there was no significant difference in all cultivars

Table 5. Functional properties of soybean cultivars

Samples	Hydration Capacity (g/cotyledon)	Hydration Index	Swelling Capacity (ml/cotyledon)	Swelling Index	Foam capacity & Stability (cm^3)	Oil Absorption (ml/g)	Water Absorption (ml/g)	Bulk Density (g/cm^3)
TGX1987-10F	0.12 ± 0.00^{a}	1.34 ± 0.02^{d}	0.21 ± 0.00^{a}	2.25 ± 0.03^{c}	127 ± 1^{c}	5.64 ± 0.24^{ab}	3.81 ± 0.07^{b}	0.68 ± 0.00^{c}
TGX 1989-19F	0.18 ± 0.01^{d}	1.12 ± 0.02^{a}	0.32 ± 0.00^{d}	1.97 ± 0.02^{a}	117 ± 1^{a}	5.78 ± 0.54^{b}	3.82 ± 0.12^{b}	0.63 ± 0.00^{b}
TGX 1835-10E	0.16 ± 0.01^{c}	1.21 ± 0.00^{b}	0.29 ± 0.00^{c}	2.18 ± 0.03^{b}	123 ± 5^{bc}	5.79 ± 0.16^{b}	3.49 ± 0.07^{a}	0.68 ± 0.00^{c}
TGX 1987-62F	0.15 ± 0.02^{b}	1.27 ± 0.01^{c}	0.27 ± 0.01^{b}	2.31 ± 0.05^{c}	123 ± 1^{bc}	5.15 ± 0.22^{a}	3.73 ± 0.16^{b}	0.69 ± 0.00^{c}
TGX 1988-5F	0.20 ± 0.00^{e}	1.21 ± 0.01^{b}	0.36 ± 0.00^{e}	2.17 ± 0.00^{b}	120 ± 0^{ab}	5.91 ± 0.12^{b}	3.5 ± 0.01^{a}	0.61 ± 0.00^{a}

Values are means± standard deviation. Means in a column with the same superscript letters are not significantly different ($P \geq 0.05$).

Functional Properties of Soybean Cultivars

Functional properties are important in predicting the physical behaviour of food or its ingredient during biotransformation and storage thereby altering the sensory properties of the food (Tiwari *et al*., 2008). Table 5 gives a detailed result on the functional properties of the five soybean cultivars that was analyzed.

Hydration Capacity (g/cotyledon)

Hydration capacity mean scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 0.12g/cotyledon, 0.18g/cotyledon, 0.16g/cotyledon, 0.15g/cotyledon and 0.20g/cotyledon respectively. Hydration is necessary before germination of seeds. Hydrating the reserve food material of seeds helps to initiate the metabolic activity responsible for the growth of the seed (Sibian *et al*., 2013). The values ranged between 0.12g/cotyledon – 0.20g/cotyledon with TGX 1987-10F having the minimum value and TGX 1988-5F having the maximum value, it was observed that there was significant difference in all cultivars.

Hydration Index

Hydration index mean scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 1.34, 1.12, 1.21, 1.27 and 1.21 respectively. The values ranged between 1.12 - 1.34 with TGX 1989-19F having the minimum value and TGX 1987-10F having the maximum value, it was observed that there was no significant difference ($P<0.05$) in mean scores between TGX 1835-10E and TGX 1988-5F, however there was significant difference in TGX 1987-62F, TGX 1989-19F and TGX 1987-10F.

Swelling Capacity (ml/cotyledon)

Swelling capacity mean scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 0.21ml/cotyledon, 0.32ml/cotyledon, 0.29ml/cotyledon, 0.27ml/cotyledon, 0.36ml/cotyledon respectively. Swelling capacity and index helps to determine the absorption rate of the seed as well as some physical properties which might be due to alteration of the cell wall (Sibian *et al*., 2013). The values ranged between 0.21ml/cotyledon - 0.36ml/cotyledon with TGX 1987-10F having the minimum value and TGX 1988-5F having the maximum value, it was observed that there was no significant difference in all cultivars.

Swelling Index

Swelling index mean scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 2.25, 1.97, 2.18, 2.31 and 2.17 respectively. The values ranged between 1.97 - 2.31 with TGX 1989-19F having the minimum value and TGX 1987-62F having the maximum value. No significant difference in mean score was between samples TGX 1835-10E and TGX 1988-5F. No significant difference ($P<0.05$) in mean scores was also observed between TGX 1987-62F and TGX 1987-10F. The mean score of sample TGX 1989-19F was however different from that of other samples. A significant difference however occurred between samples.

Foam Capacity and Stability (cm^3)

Foam capacity and stability mean scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 127cm^3, 117cm^3, 123cm^3, 123cm^3 and 120cm^3 respectively. The values ranged between

117cm^3 - 127cm^3 with TGX 1989-19F having the minimum value for mean score and TGX 1987-10F having the maximum value for mean scores among the samples in this study. Significant difference ($P \leq 0.05$) in mean score was observed between samples, however no significant difference ($P \geq 0.05$) in mean score was observed between samples TGX 1835-10E and TGX 1987-62F.

Oil Absorption Capacity (ml/g)

Oil absorption capacity mean scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 5.64ml/g, 5.78ml/g, 5.79ml/g, 5.15ml/g and 5.91ml/g respectively. Oil absorption capacity is significant in food industries for retention of flavour in foods and improvement of shelf life and palatability (Falade *et al*., 2015). The result of oil absorption capacity obtained ranges from 5.15ml/g - 5.91ml/g with TGX 1987-62F having the minimum value and TGX 1988-5F having the maximum value. There was no significant difference ($P > 0.05$) observed in mean scores between TGX 1988-5F, TGX 1835-10E and TGX 1989-19F, however there was a slight significant difference ($P < 0.05$) between TGX 1987 10F and the other samples.

Water Absorption Capacity (ml/g)

Water absorption capacity mean scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 3.81ml/g, 3.82ml/g, 3.49ml/g, 3.73ml/g and 3.50ml/g respectively. The values ranged between 3.49ml/g - 3.82ml/g with TGX 1835-10E having the minimum value and TGX 1989-19F having the maximum value. Significant differences were obtained in mean scores for some cultivars in this study. No significant difference was however observed in mean scores between samples TGX 1987-10F, TGX 1989-19F and TGX 1987-62F. There was also no significant difference ($P > 0.05$) was obtained between the mean scores of 1988-5F and TGX 1835-10E. Water absorption capacity determines the quantity of water or oil absorbed by the flour to achieve the desired consistency. It is of significance when determining the attributes and shelf life of the products.

Bulk Density (g/cm^3)

Bulk density mean scores values obtained for cultivars, TGX 1987-10F, TGX 1989-19F, TGX 1835-10E, TGX 1987-62F, TGX 1988-5F in this study are 0.68 g/cm^3, 0.63 g/cm^3, 0.68 g/cm^3, 0.69 g/cm^3 and 0.61 g/cm^3 respectively. The values of mean scores for bulk density ranged between 0.61g/cm^3 – 0.69g/cm^3 with TGX 1988-5F having the minimum value and TGX 1987-62F having the maximum value, it was observed that there was no significant difference ($P < 0.05$) between sample cultivars TGX 1987-62F, TGX 1835-10E and TGX 1987-10F, and there was significant difference between TGX 1989-19F and TGX 1988-5F. Bulk density is the mass of the particles that occupies a unit volume. Bulk density is relevant in food processing, when carrying out quality control in the food industry. It also determines whether a raw material can be mixed or a final product can be packed in a predetermined container. It also determines the intentional and unintentional compression that a powdery substance suffers during transport or production (Gustavo *et al*., 2005).

CONCLUSION

Soybean seeds were characterized for physical, chemical, mechanical and functional properties. The proximate composition of the Soybean cultivars studied were not significantly ($P \leq 0.05$) different in the moisture content, fat content, crude fibre and carbohydrate while significant ($P \leq 0.05$) difference was observed in protein and ash content. Mechanical and functional properties were significantly ($P \leq 0.05$)

different among cultivars. The results of this study is useful in predicting potential uses of these five cultivars of grains in food processing preservation, food handling, storage and distribution.

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