IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 16, Issue 3 Ser. II (March 2022), PP 43-51
www.iosrjournals.org

Measurement of Engineering Properties of three varieties of Cowpea (*Vigna unguiculata L. Walp)* seeds.

*Amadi, N. V.[1] and Okorie, S. U.[2]
[1]*Department of Food Technology, Federal Polytechnic Nekede, Owerri, Imo State, Nigeria.*
[2]*Department of Food Science and Technology, Imo State University, Owerri, Imo State, Nigeria.*
** corresponding author: nnekauzonna@yahoo.com*

Abstract: *Selected engineering (physical and mechanical) properties of three varieties of cowpea (Vigna unguiculata L. Walp) seeds (black crowder, brown crowder and gray speckled palapye) were investigated. The physical and mechanical properties showed that the average length, width, and thickness were 6.96mm, 5.13mm and 3.63mm at a moisture content of 5.26% (wb) for the black crowder cowpea; 6.95mm, 5.04mm and 3.60mm at a moisture content of 5.63% (wb) for the brown crowder cowpea and 7.30mm, 5.28mm and 3.71mm at a moisture content of 6.08% (wb) for the gray speckled palapye cowpea respectively. The seeds were generally small sized. The result further showed that the geometric mean diameters were 5.06mm, 5.01mm and 5.23mm while the arithmetic mean diameters were 5.24mm, 5.20mm and 5.43mm for the black crowder, brown crowder and gray speckled palapye cowpea seeds respectively. The cowpea seeds were closer to a sphere in shape with the black crowder, brown crowder and gray speckled palapye cowpea seeds having a sphericity of 0.73, 0.72 and 0.72 respectively. The mean surface area which were 79.91mm^2, 79.00mm^2 and 85.92mm^2 and the mean specific surface areas which had the values 5.48mm^2/mm^3, 7.38mm^2/mm^3 and 5.97mm^2/cm^3 for black crowder, brown crowder and gray speckled palapye cowpea seeds respectively, showed that the seeds have large surface and specific surface areas. The mean values of volume were 11.58mm^3, 11.18mm^3 and 12.14mm^3; bulk density, 0.80gm^3 ,0.76gm^{-3} and 0.75gm^3; true density, 1.03gcm^{-3} ,1.01gcm^{-3} and 0.99gcm^{-3};unit seed mass, 0.12g, 0.08g and 0.11g; one thousand seed mass, 124.00g, 81.03g and 108.03g and porosity, 22.22%, 24.99% and 23.60% for the black crowder, brown crowder and gray speckled palapye cowpea seeds respectively. The mean values of angle of repose (filling and emptying) of the cowpea seeds indicated that they would readily form heaps during collection/packaging and would readily flow out during emptying of the holding vessels or hoppers. The mean values for the coefficient of static friction on various surfaces indicated that glass offered the highest resistance to flow to the cowpea seeds, followed by plywood, aluminum, formica and stainless steel accordingly. All the values obtained may be exploited in the design and fabrication of suitable equipment/system to sort, grade, handle, convey, process, and store the various cowpea seeds.*

Background: *Cowpeas play an important role in being among the easily accessible sources of plant protein. However, there is dearth of information on the physical and mechanical properties of cowpeas (black crowder, brown crowder and gray speckled palapye) seeds cultivated and consumed in Nigeria. There are always unwanted materials in all the harvested seeds; sorting and cleaning the seeds is too slow, labour-intensive and time-consuming – all of which could be resolved with accurate data for process mechanization.*

Materials and Methods*: The dry mature seeds of the three cowpea samples were manually cleaned to remove all unwanted matters such as stones, dust, dirt, seed pods, metals, chaff, immature and broken seeds. They were then analyzed for the various engineering properties.*

Results: *The various cowpea samples had a range of mean values as follows: Length 6.95-7.30mm, width 5.04-5.28mm, thickness 3.60-3.71mm and a 1,000-seed weight of 81 - 124g. The bulk density was highest for black crowder cowpea, followed by brown crowder and gray speckled palapye cowpeas. Coefficient of friction against glass produced significantly higher frictional resistance to the motion of the cowpea seeds as compared to all the other test surfaces*

Conclusion: *The cowpea seeds were small sized. Size and shape could be utilized in the design of aperture sizes of size sorting equipment particularly in the separation of materials. The shape of the seeds, on the basis of sphericity showed the seeds shape were closer to a sphere, and had more tendency to roll than to slide. The mean values of volume, bulk density, solid density, unit seed mass, one thousand seed mass and porosity values specified that the cowpea seeds will not float in water and these values would help to separate unwanted materials from the seeds during wet cleaning based on buoyancy differences. The coefficient of static friction of the seeds is considered highest for glass, followed by aluminium, plywood, formica and stainless steel in that order.*

Key words: Cowpea, Engineering properties, Black crowder cowpea, Brown crowder cowpea

----

Date of Submission: 15-03-2022 Date of Acceptance: 31-03-2022

I. Introduction

The crop, cowpea [*Vigna unguiculata* (L.) Walp] refers to an annual herbaceous and leguminous plant, with centre of origin and domestication reported to be in Africa. According to [1], cowpea belongs to the family, *Leguminoseae* and the sub-family, *Papilionadeae*. It is a major member of the well-cultivated *Vigna* cultivars, in the midst of the over 25 – 26 commonly grown pulses chosen from 600 – 700 clans (*genera*) and over 18,000 species of the *Leguminoseae* family of the flowering plants.

Nigeria happens to be the largest producer and end user of cowpea [3] accounting for 61% of production [4]. Available data [5] indicate that West Africa sub-region produced about 81% (4,525 metric tonnes) of the global production of cowpea (5,589,216 metric tonnes) in 2014. Nigeria's production of 2,137,900 metric tonnes for the same period accounted for 38.3% and 47.2% of global and West African production respectively. Consequently, Nigeria has remained the largest producer of the commodity.

Varieties of cowpea available in Nigeria include Ife brown, IT80D-699, IT82(e-18), IT828-146, IT870-9411, IT90K-277-2 and TVX3236 [6]. Those identified by their local names according to [2]include akidi, kafanji, aloka, apama, orarudi, kwana, and others. These varieties differ in size, colour of the seed coat and/or helium, and shape of the cotyledon. They also show variations in proximate composition, functional properties and length of time of cooking and taste after cooking. [3] reported that cowpea seeds differ in physical form, ranging from kidney shape to spherical configuration. The pods bearing the seeds usually hold about eight and eighteen seeds in each pod – the latter being straight, cylindrical or curved. The *testa* (seed coat) fluctuates in textural patterns (wrinkled, rough or smooth), colouration (black, red-brown, buff, cream or white) and homogeneity (patterned, speckled or solid).

Cowpea is a major essential diet in African and Asian Continents [7] and it is a critical source of income in the developing countries of the tropics, which is germane to the survival of millions of indigent segments of the population [8]. [9]cited in [6], reported that all sections of the plant utilized as food possess nutrient density, and supply proteins and vitamins; as juvenile leaves, green-coloured pods and greenish seeds are ingested as vegetables, while dry seeds are employed in the preparation of multiple snacks and primary meals/cuisines.

[10] indicated that cowpea seeds are of high market, cultural and economic benefit due to its high local consumption and cultural significance. The crop is unique in that it provides food, cash and fodder [11]. Going past its importance for food and feed as stated by [12], cowpea can be considered as a fulcrum of sustainable farming in areas known by systems of farming that make insufficient utilization of nitrogen and provide roughly 60 – 70 kg/ha nitrogen for sequentially-grown crops in rotation. [13] in conjunction with [14] posited that cowpea is an exceptionally hardy crop and is cultivated within some of the most unconducive farming conditions in the globe.

In the developing countries, small-scale farmers are the principal producers of cowpea and a high proportion of the cowpea produced is consumed on the farm or traded only in the local markets. There is hardly any food processor of cowpea that possesses mechanized equipment for harvesting, handling or processing. Most subsistent small-scale producers perform the key operations manually which yields a product with poor quality and low nutrient. Cowpeas are harvested and collected manually by hand-picking. There are always unwanted materials in all the harvested seeds and it is too slow, labour intensive and time consuming and despite the important role played by cowpea in being among the easily accessible sources of plant protein, there is dearth of information on the physical and mechanical properties of cowpeas (black crowder, brown crowder and gray speckled palapye) seeds cultivated and consumed in Nigeria.

According to [15], there is a general tendency to effect mechanization of agricultural and food production because of daily rising labour cost (due to aging population or rural farmers, rural-urban migration, etc), shortage in hand labour and to save time and efforts.

Properties of food items are assessed to compute the engineering properties which can be made use of, in the design of appropriate machines and equipment for handling, processing and storage of these products [16]. For example, size and shape of the materials are fundamental in separation processes including sorting, sizing, grading amongst others; Bulk density and true density of food materials are needed to be known so as to effectively design equipment to be used in sorting, grading, processing, transportation and storage of the food materials; its angle of repose is necessary for designing packages or storage structures and the coefficient of friction of the food materials on different surfaces is highly important while handling and transporting the food materials from one point to another and is equally important while constructing storage structures [17].

This study investigated and ascertained the engineering properties of the cowpea seeds, considering such parameters as moisture content, axial dimensions (length, width and thickness), geometric mean diameter, arithmetic mean diameter, bulk density, porosity, surface area, specific surface area ,solid density, true density, sphericity, one thousand seed mass, coefficient of static friction on multiple probable food contact surfaces, angle of repose, specific heat, thermal conductivity and thermal diffusivity.

The knowledge of these physical and mechanical properties constitutes a highly indispensable engineering data which is used in the designing of machines for food processing, designing of storage structures, and equally for the intent of quality control and this will help in lessening the labour involved and increase the sanitation of the processing condition. This key information is useful to food engineers and also to those who may make use of these important properties and find new ways of using the plant material.

II. Materials And Methods

Dry mature seeds of the black crowder, brown crowder and gray speckled palapye cowpea seeds were procured from Ose market, Onitsha, Anambra state, Nigeria.

Study Design: Experimental observational study.

Study Location: Nekede Autonomous Community, Owerri-West Local Government Area of Imo State, Nigeria. **Study Duration:** November, 2020 to March, 2021.

Procedure methodology

Preparation of cowpea samples for analysis

The three cowpea samples were prepared using the amended methods given by [18] and [19]. The cowpea seeds were manually cleaned to remove all unwanted matters such as stones, dust, dirt, seed pods, metals and chaff. Immature and broken seeds were equally removed and after that, the cleaned cowpea seeds were kept in covered containers for subsequent analysis.

Plate 1: Black crowder cowpea

Plate 2: Brown crowder cowpea

Plate 3: Gray speckled palapye

Moisture content determination

Moisture content was determined according to the method described by [20] . The method No. 945.38 was used.

Determination of the selected engineering properties.

Dimensional measurements

(i) Geometric mean diameter (Dg)

The method of [18] was adopted.

(ii) Arithmetic Mean diameter (Da)

Arithmetic mean diameter was obtained by using the formula as presented by [21].

(iii) Volume (V)

This was ascertained using the mathematical relationship presented in, and adopted by [21].

(iv) Sphericity (φ)

This was determined mathematically based on the mathematical relationship used by [22].

(v) Surface area (S)

This was determined mathematically according to the formula used [17].

*(vi) Specific surface area **(Ss)***

This was derived using the mathematical relationship presented by [19].

Gravimetric measurement

(i) Thousand-seed mass

The method of [18] was adopted.

(ii) Bulk density and true density

Bulk density value was obtained according to the method expressed by [18], while the true density was calculated based on the method given by [19].

(iii) Porosity (P)
Porosity was calculated using the relationship described by [19].

Frictional properties measurement
(i) Filling angle of repose and emptying angle of repose
The Filling angle of repose and Emptying angle of repose were obtained by using the method given by [23].

(ii) Static coefficient of friction (μ)
The method of [22] was used to determine the Static coefficient of friction of the cowpea seeds on five structural materials (test surfaces) which included: Plywood, Glass, Aluminium, Stainless steel and Formica.

III. Results

Table no 1: Moisture content wet-weight and dry-weight bases of the three cowpea varieties.

Samples	Moisture content wet- basis (%)	Moisture content dry-basis (%)
BLC	5.26	5.55
BRC	5.63	5.97
GPC	6.08	6.47

Key
BLC = Black crowder cowpea
BRC= Brown crowder cowpea
GPC= Gray speckled palapye cowpea

Table no 2: Dimensional properties of the three cowpea varieties.

Dimensional property	Cowpea varieties	N	Average values	Standard Deviation	Maximum values	Minimum values
Length (mm)	BLC	100	6.96	±1.37	8.16	6.22
	BRC		6.95	±1.61	7.88	5.60
	GPC		7.30	±2.10	8.14	5.57
Width (mm)	BLC	100	5.13	±1.76	6.71	4.22
	BRC		5.04	±1.61	5.88	3.60
	GPC		5.28	±1.91	6.01	3.31
Thickness(mm)	BLC	100	3.63	±0.56	4.09	3.13
	BRC		3.60	±0.88	3.92	3.20
	GPC		3.71	±0.85	4.23	3.00
Geometric mean diameter (mm)	BLC	3	5.06	±0.85	5.56	4.35
	BRC		5.01	±1.17	5.66	4.01
	GPC		5.23	±1.49	5.91	3.81
Arithmetic mean diameter (mm)	BLC	3	5.24	±1.14	6.14	4.52
	BRC		5.20	±1.24	5.89	4.13
	GPC		5.43	±1.53	6.13	3.96
Sphericity	BLC	3	0.69	±0.01	0.70	0.68
	BRC		0.72	±0.00	0.72	0.72
	GPC		0.74	±0.03	0.76	0.70
Volume (mm^3)	BLC	3	11.58	±5.74	16.48	8.36
	BRC		11.18	±5.02	14.25	7.14
	GPC		12.14	±6.48	15.56	6.04
Surface area (mm^2)	BLC	3	79.91	±26.57	96.96	59.38
	BRC		79.90	±35.52	100.77	50.54
	GPC		85.92	±45.47	109.93	45.61
Specific surface area (mm^2/cm^3)	BLC	3	5.48	±1.82	5.63	3.78
	BRC		7.38	±3.38	9.49	4.71
	GPC		5.97	±3.12	7.58	3.16

Key:
BLC = Black crowder cowpea; BRC= Brown crowder cowpea; GPC= Gray speckled palapye cowpea

Table no 3: Gravimetric properties of the three cowpea varieties.

Gravimetric property	Cowpea varieties	N	Average values	Standard Deviation	Maximum values	Minimum values
Unit seed mass (g)	BLC	3	0.12	±0.00	0.12	0.12
	BRC		0.08	±0.00	0.01	0.08
	GPC		0.11	±0.00	0.11	0.11
One thousand seed mass(g)	BLC	3	124.00	±0.14	124.10	123.90
	BRC		81.03	±0.07	81.10	81.01
	GPC		108.03	±0.07	109.0	108.0
Bulk density (gm^{-3})	BLC	3	0.80	±0.05	0.82	0.79
	BRC		0.76	±0.00	0.76	0.76
	GPC		0.75	±0.00	0.75	0.75
Solid density (gm^{-3})	BLC	3	1.03	±0.00	1.03	1.033
	BRC		1.01	±0.00	1.014	1.01
	GPC		0.99	±0.00	0.991	0.98
Porosity (%)	BLC	3	22.22	±1.96	23.58	20.81
	BRC		24.99	±0.50	26.12	25.41
	GPC		23.60	±4.44	23.72	17.43

Key: BLC = Black crowder cowpea; BRC= Brown crowder cowpea; GPC= Gray speckled palapye cowpea

Table no 4: Filling and emptying angles of repose of the three cowpea varieties.

Frictional property	Cowpea varieties	N	Average values	Standard Deviation	Maximum values	Minimum values
Angle of repose						
Filling angle of repose	BLC	3	3.72	±0.00	3.727	3.713
	BRC		4.29	±0.04	4.312	4.266
	GPC		4.35	±0.02	4.362	4.329
Emptying angle of repose	BLC	3	26.72	±0.08	26.686	26.565
	BRC		33.59	±0.03	33.607	33.570
	GPC		30.31	±0.03	30.342	30.272

Key: BLC = Black crowder cowpea; BRC= Brown crowder cowpea; GPC= Gray speckled palapye cowpea

Table no 5: Coefficient of static friction of the three cowpea varieties on different surfaces.

Dimensional property	Cowpea varieties	N	Average values	Standard Deviation	Maximum values	Minimum Values
Coefficient of static friction						
For plywood	BLC	3	0.87	±0.04	0.894	0.841
	BRC		0.81	±0.00	0.814	0.814
	GPC		1.06	±0.01	1.064	1.055
For glass	BLC	3	1.08	±0.01	1.087	1.078
	BRC		1.10	±0.00	1.096	1.096
	GPC		1.19	±0.02	1.212	1.176
For formica	BLC	3	0.78	±0.04	0.810	0.756
	BRC		0.73	±0.03	0.765	0.694
	GPC		0.82	±0.02	0.836	0.801
For aluminium	BLC	3	0.89	±0.01	0.893	0.884
	BRC		0.87	±0.01	0.884	0.866
	GPC		1.05	±0.02	1.063	1.036
For stainless steel	BLC	3	0.75	±0.00	0.755	0.750
	BRC		0.71	±0.06	0.751	0.663
	GPC		0.83	±0.03	0.819	0.854

Key: BLC = Black crowder cowpea; BRC= Brown crowder cowpea; GPC= Gray speckled palapye cowpea

IV. Discussion

Moisture content

The moisture content wet-weight basis and dry weight basis for the cowpea samples were obtained. The seeds can be said to be generally low in moisture content. The low moisture content arises from natural sun-drying [24]. According to [25], moisture content determination is important as it is a key parameter which has an influence on all processing procedures and other physical and engineering properties. It is a compositional property of agricultural materials [24], it is dynamic and can fluctuate greatly due to changes in seasonal temperature, solar intensity and relative humidity.

Size and shape of seeds

The values obtained for length, width and thickness indicated that the gray speckled palapye cowpea was larger than the black crowder cowpea which was larger than the brown crowder cowpea and it is in all likelihood, a function of species diversity. This variance could be made use of in the design of aperture sizes of size-sorting equipment [21] in instances where mixed seed sizes occur and particularly in the separation of materials [25]. Generally, the seeds examined were small-sized. According to [26], the size of seeds determines occupation of space, which is based on the seed or kernel morphometric dimensions which include length, width and thickness. [27] also stated that length, width and thickness, which are the three measurements along the mutually perpendicular axes are used to specify the shape of the food material. The two statements above implicated length, width and thickness as parameters used to determine the size and shape of the seed.

The sphericity (ϕ) value, which is close to 1.0, results in higher tendency of the seed to roll about any of the three axes (length, width and thickness). The values obtained for the sphericity of the cowpea varieties indicated that BLC will have an increased tendency to roll on a surface than BRC and GPC, as a lower sphericity is an indication that the seed cannot roll on its side, but slide when suitably inclined. Sphericity as stated by [28] is relevant in the conceptualization of hoppers where decision is based on rolling or sliding characteristics of agricultural produce and handling machines. [29] emphasized that size, shape and sphericity are important physical attributes used in screening solids to separate foreign materials, grading and evaluating the quality of foods. They are also important parameters in heat and mass transfer calculations.

Diameter

Geometric mean diameter and Arithmetic mean diameter are functions of the length, width and thickness and as such since the length, width and thickness of morama bean (*Tylosema esculentum*) studied by [24] were higher than that of the local cowpeas, the Dg and Da of the morama beans were also higher than that of the local cowpea varieties. According to [24], the geometric mean diameter of a material is an expression of its size as one-dimensional quantity measured in three dimensions. As the geometric mean diameter is a measure of size from three dimensions, it would be useful in determining aperture or size of openings in seed processing and handling equipment.

Volume, surface area and specific surface area

From the values obtained for volume of the various cowpea varieties, GPC would occupy more space than BLC and BRC with the fewer number of seeds, that is, the bulk of the seeds of BRC would be contained by the same vessel than would enclose (being filled with) a lower quantity of GPC. The size, surface area and volume of seeds are considered in bulk handling and processing operations, especially in heat and mass transfer [30].

The average values of surface area of the seeds were 79.91mm^2, 79.00mm^2 and 85.92mm^2 for BLC, BRC and GPC respectively. The surface area of food materials is important in handling and processing operations, especially in calculating the terminal velocity of the materials which is utilized in aero- and hydrodynamic activities such as pneumatic conveying and separation processes where the material is lifted only when the air velocity is greater than its terminal velocity, thus, having an effect on the air stream that can be used in order to separate the seed from unwanted materials as done by pneumatic separators, or to move seeds as done by pneumatic conveyors [31]. According to [32], surface area and volume of legume seeds are important physical characteristics in processes such as harvesting, cleaning, separation, handling, aeration, drying, storing, milling, cooking and germination of seeds and according to [26], they are useful in designing the seed cleaners, seperators and conveyors.

Increased surface area to volume ratio raises heat and mass transfer rate of seeds or kernels, thus, facilitating drying, cooking, cooling and heating operations [33] and [1]. From the result obtained, BLC would exhibit lesser mass or heat transfer rate through its surface, GPC would exhibit less while BRC would exhibit more mass or heat transfer rate through its surface. As particle size decreases, the surface area per unit volume increases, so, it will be easier to dry the small sized cowpea seeds than other large sized seeds.

One thousand seed mass, bulk density, solid density and porosity

Table no 3 presents the results of unit mass, one thousand seed mass, bulk density, solid density and porosity. The average value for one thousand seed mass (M_{1000}) of the local cowpeas was 124.00g for black crowder cowpea (BLC), 81.03g for brown crowder cowpea (BRC) and 108.03g for gray speckled palapye cowpea (GPC). This wide disparity was expected as the variation in surface area, bulk density and volume implied that the possibility of BLC containing more matter within it was highest, followed by GPC while the least was BRC. According to [34], 1000-grain mass is suggestive of maturity and growing condition that crops have been exposed to.

Legume seeds were classified by [35] into size categories based on their 1000 – seed weight. Varieties with seeds weighing 100 – 150g are described as small, 151 – 200g are medium-sized seeds while large seeds have 201 – 250g weight range. Seeds weighing over 250g are described as very large seeds. According to the above classification, the cowpea varieties analyzed in this work were small-sized when compared with other commonly grown pulses.

Bulk density is an important parameter in aeration, loading and drying system of agricultural seeds while true density is important in developing a separation system for the seeds [36]. The bulk density for BLC was shown to be more than that of BRC and GPC respectively. It was probably due to the fact that the weight of BLC occupied by a particular volume was higher than the weight of BRC and GPC occupied the same volume. The bulk density of the agricultural products plays an important role in many applications like sizing, and storing in storage facilities.

It was observed that the seeds with the smallest linear dimensions had the greatest bulk density. This could be adduced to the fact that smaller seeds are likely to be well compacted than the larger seeds [36]. Bulk density (ρ_b) is not an intrinsic property of a material as it can change depending on how the material is handled, the interaction between the surfaces of the material in contact and the degree of intensity of the compaction process [37]. According to [25], bulk density is an indicator of quality and an important parameter of breakage susceptibility and hardness study.

The mean solid density (ρ_s) values indicated that the cowpea seeds would sink in water, being denser than water ($\rho = 1.0$ gm^{-3}) as was evident during the analytical process. This property could be optimized when separating the local cowpea seeds from less dense contamination (eg husks, chaff, spoilt seeds etc) during wet cleaning operation, especially via soaking. According to [25], true density is useful in calculating product yield and throughput in processing machinery.

The average porosity (P) of the various bean samples were 22.22%, 24.99% and 23.60% for BLC, BRC and GPC respectively. This implied that while the seeds do not hydrate easily, the seed with the highest porosity (24.99%) will hydrate more easily; that is, BRC will hydrate more easily, followed by GPC and then BLC. Porosity was indicative of the volume fraction of void space or air inside the material, which accounts for the interaction of components and formation/ collapse of air or void phase during processing [38]. Porosity is an essential characteristic according to [39], used in the calculation of rate of aeration, cooling, drying, heating and design of heat exchanger and packaging equipment. Porosity is an important data necessary in the design of aeration systems during storage. The higher the porosity the better the aeration and water vapour diffusion during deep-bed drying [26]. The porous properties of food materials determine key microscopic parameter such as water holding capacity and texture [40]. Diffusion coefficient is enhanced by increase in porosity which, in turn, is affected by the water content of foods. An increase in the moisture content of food leads to swelling of the components and a subsequent decrease in porosity of the food material [41].

Angles of repose

The mean filling angle of repose showed that the various cowpea seeds would readily form heaps during collection/ packaging. This was in line with the true assertion of [23] that seeds of smaller sizes can interlock more to cause a higher heap formation than seeds of relatively bigger sizes. Still, the angular variation may not be critical enough to result in any wide disparity, and may be a function of the shape/size of the seed and surface conditions of the seeds which influence their cohesion/adhesion characteristics [15]. According to [42], angle of repose is important in filling of flat storage facility when seed is not collected at a uniform bed depth but rather peaked.

The mean of emptying angle of repose (θe) obtained for BLC, BRC and GPC were 26.62^o, 33.59^o and 30.31^o respectively. This implied that BLC (26.62^o), seemed to have a somewhat slightly smoother surface than GPC (30.31^o) and BRC (33.59^o) and will readily flow off self-emptying bins or hoppers during raw material reception or processing when the vessel bearing them are tipped at an angle. According to [43], angle of repose is a benefic parameter for optimum design of hopper. The angle of inclination of the hopper wall should be larger than the angle of repose of the grain to guarantee the continuous flow of grain by gravitational force.

Coefficient of static friction (μ) on various surfaces

Frictional properties of cowpea varieties were determined using different sliding surface materials including plywood, glass, formica, aluminum and stainless steel and values obtained are shown in Table no 5. The coefficient of static friction of the seeds is considered highest for glass, followed by aluminium, plywood, formica and stainless steel in that order. Coefficient of friction against glass would produce significantly, higher frictional resistance to the motion of the cowpea seeds as compared to all the other test surfaces. The cowpea varieties showed the lowest coefficient of static friction on stainless steel. Stainless steel also offered minimum friction for jatropha seeds [26]. This may be attributed to polished and smoother surface of stainless steel compared to other test surfaces used. Lower moisture content and smooth surfaces of seeds resulted in the easy movement on the test surfaces.

Generally, glass, aluminium and plywood were observed to have offered some resistance to sliding of the box of seeds carrying the three varieties of the cowpea seeds, although the size and weight of the seeds, as well as the packaging differences of the seeds in the box, and surface characteristics of each of the structural surfaces used (even at the microscopic level) may have resulted in the degree of disparities. This observation may make a case for using less expensive, natural sources of contact when selecting and determining the slopes of feed hopper of cowpea processing equipment, or in the design of seed hopper in mechanical planters.

According to [44], coefficient of friction is critical in designing equipment for solid flow and storage structures. The coefficient of friction between grains and wall is an important parameter in the prediction of grain pressure on walls. In other words, coefficient of friction influences the lateral pressure that grains experience in silo/bin storage [24].

The angle of repose and coefficient of friction are important grain flow parameters which influence the design of seed containers and other storage vessels. Furthermore, the static coefficient of friction limits the maximum angle of inclination of conveyors and hoppers of storage bins and the power requirement for conveyors depends on the magnitude of the frictional force [24]. So, hopper and other unloading devices need not be too sloppy because of the relatively low coefficient of static friction of the seeds.

V. Conclusion

Physical, mechanical, and thermal properties are of vital importance in many challenges associated with the design of machines and in the analysis of the behaviour of various products during agricultural processing operations. The present study provided the basic information on selected engineering (physical and mechanical) properties of three varieties of cowpea seeds namely: black crowder cowpea, brown crowder cowpea and gray speckled palapye cowpea.

The cowpea seeds were small sized. Size and shape could be utilized in the design of aperture sizes of size sorting equipment particularly in the separation of materials. The shape of the seeds, on the basis of sphericity showed the seeds shape were closer to a sphere, and had more tendency to roll than to slide.

The mean values of the surface and specific surface area implied that the three varieties of cowpea seeds would fall through a stream of air at the right velocity while lighter/irregularly-shaped chaff/extraneous matter will be blown away during pneumatic separation processes such as aspiration/winnowing. As particle size decreases the surface area per unit volume (in mass) increases, so it will be easier to dry the cowpea seeds than other large sized seeds.

The mean values of volume, bulk density, solid density, unit seed mass, one thousand seed mass and porosity values specified that the cowpea seeds will not float in water and these values would help to separate unwanted materials from the seeds during wet cleaning based on buoyancy differences.

The mean values of angle of repose showed that during collection/packaging, the three samples of cowpea seeds would readily form heaps and during emptying of the holding vessel or hoppers, the three samples of cowpea seeds would readily flow out, during raw material reception or processing when the vessel bearing them was tipped at an angle.

The coefficient of static friction on various test surfaces showed that glass offered the highest resistance to the flow of the local cowpea seeds, followed by plywood, aluminum, formica and stainless steel.

References

[1]. Carlos, G. Cowpea: Post harvest operations. INPhO- Post-harvest compendium; Food and Agricultural Organization of the United Nations (FAO), Rome, Italy. 2004; pp 2 - 64.

[2]. Enwere, N. J. *Foods of plant origin*. Enugu: Afro-Orbis Publications Limited, 1998; pp 40 – 48.

[3]. Tariku, S. Breeding cowpea (*Vigna unguicalata L. Walp*) for quality traits. *Annals of Reviews and Research,* 2018*;* 3 (2): 0045 - 0051.

[4]. IITA. *Crops*. [Online]. 2009; Available: http:www.iita.org [Accessed 2021 May, 01].

[5]. FAO. FAOSTAT online statistical services: Crop production data. Food and Agricultural Organization of the United Nations (FAO), Rome. 2017; Available at: http/www.fao.org/faostat/e/#data/QC (accessed on: 24 August,2017).

[6]. Agbogidi, O. M. and Egho, E. O. Evaluation of eight varieties of cowpea (*Vigna unguicalata (L) Walp*) in Asaba agro-ecological environment, Delta State, Nigeria. *European Journal of Sustainable development*, 2012; 1 (2): 303 - 304.

[7]. Awe, O. A. Preliminary evaluation of the three Asia yard's long cowpea lines in Ibadan, Southern Western Nigeria In: Proceedings of the 42nd Annual Conference of ASN held at Ebonyi State University Abakaliki, Nigeria.19th to 23rd October, 2008. 2008; pp 246-249.

[8]. FAO. World Agriculture: Towards 2015/ 2016. Summary report. Rome. 2002.

[9]. Islam, S., Cowmen, R. C. and Ganer, J. O. Screening for tolerance of stress temperature during germination of twenty-five cowpea (*Vigna unguiculata L. Walp*) cultivars. *Journal of Food, Agriculture and Environment*, 2006; 4 (2): 189 - 191.

[10]. Ngompe-Deffo, T., Kouam, E. B., Beyegue-Djonko, H. and Anoumaa, M. Evaluation of the genetic varieties of cowpea landraces (*Vigna unguiculata*) from Western Cameron using Qualitative traits. *Not Sci. Biol*, 2017; 9 (4): 508 - 514.

[11]. Saka, J. O., Agbeleye, O. A., Ayoola, O. T., Lawal, B. O., Adetumbi, J. A. and Oloyede-Kamiyo, Q. O. Assessment of varietal diversity and production systems of cowpea (*Vigna unguiculata(L.)Walp*) in Southwest Nigeria. *Journal of Agriculture and Rural Development in the Tropics and Subtropics,* 2018; 119 (2): 43 - 52.

[12]. Agyeman, K., Berchie, J. N., Osei-Bonsu, F, Tetteh, N. E. and Fordour, J. K. Growth and yield performances of Improved Cowpea (*Vigna unguicalata L.*) varieties in Ghana. *Agricultural Science,* 2014*;* 2 (4): 44 - 52.

[13]. Owolade, O. F., Akande, M. O., Alabi, B. S. and Adediran, J. A. Phosphorus level effects on brown biotech diseases development and yield of cowpea. *World Journal of Agricultural Science,* 2006; 2 (1): 105 - 108.

[14]. Muoneke, C. O., Ndukire, O. M., Umana, P. E., Okpara ,D. A. and Asawalam, D. O. Productivity of vegetables cowpea (*Vigna unguicalata L.* (*Walp*) and maize (*zea mays L.*) intercropping system as influenced by component density in a tropical zone of South-eastern Nigeria. *International Journal of Agricultural Research and Development,* 2012; 15 (1): 853 - 847.

[15]. Helmy, M., Derbala, A, Badr, S. and Shohyieb, S. Effect of determination of some physical properties of some Corn varieties on pneumatic machine performance. *Misr Journal or Agricultural Engineering,* 2019; 26:1379 - 1411.

[16]. Ohaegbulam, P. O., Okorie, S. U. and Ojinnaka, M. C. Evaluation of the engineering properties of African yam beans (*Sphenostylis stenocarpa*) seeds. *J. Hum Nutr. & Food Sci,* 2018; 6 (1): 11158.

[17]. Idowu, D. O., Abegunrin, T. P., Ola, F. A. Adediran, A. A. and Olaniran, J. A. Measurements of some engineering properties of sandbox seeds (*Hura crepitans*). *Agricultural Biology Journal of North America,* 2012; 3: 318 - 325.

[18]. Ahmadi, A. A., Mollazade, K., Khorshidi, J., Mohtasebi S.S and Rajabipour, A. Some physical and mechanical properties of fennel seed (*Foeniculum vulagare*). *Journal of Agric Sci.,* 2009; 1: 66 - 75.

[19]. Asoiro, F. U., Anyanwu, C. N. and Ezeoha, S. L. Mechanical and thermal properties of *Irvingia gabonensis, Detarium microcapum, Mucuna pruriens and Brachystegia eurycoma. Journal of Scientific and Engineering Research,* 2019; 6 (1): 23 - 33.

[20]. AOAC. *Official Methods of Analysis.* 17th edition. Washington, D. C. Association of Analytical Chemists. 2005

[21]. Adebowale, A. A., Fetuga, G. O., Apata, C. B. and Sanni, L. O. Effect of variety and initial moisture content on physical properties of improved millet grains. *Nigerian Food Journal,* 2012; 30: 5 - 10.

[22]. Adejumo, B. A. and Abayomi, D. A. Effect of moisture content on some physical properties of *Moringa oleifera* seed. *IOSR J. Agri. Vet. Sci.* 2012; 1: 12 - 21.

[23]. Bart-Plange, A., Dzisi, A. K., Adodo, A., Teye, E. and Kumi, F. A. A comparative study of some physical properties of large and medium size cocoa bean from Ghana. *ARPNJSCI Technology,* 2012; 2: 135 - 144.

[24]. Emesu, P. and Mabuza, P. Determination of some engineering properties of moroma bean (*Tylosema esculentum). AgriculturalEngineering international: CIGR Journal*, 2014; 16 (3): 180 - 188.

[25]. Ilori, T. A., Raji, A.O and Kilanko, O. O. Some physical properties of selected vegetable. *Journal of Agricultural and Vertinary Sciences,* 2012; 2: 101-109.

[26]. Niveditha, V.R., Sridhar, K. R. and Balasuramanian, D. Physical and mechanical properties of seeds and kernels of Canavalia of Coastal Sand dunes. *International Food Research Journal,* 2013; 20 (4): 1547 - 1554.

[27]. Yogendra, S and Suresh, C. Evaluation of physical properties of kidney beans (*Phaseolus vulgaris*). *Food Science Research Journal,* 2014; 5 (2): 125 - 129.

[28]. Olalusi, A. P. and Bolaji, O. T. Some engineering properties of indigenous grown Jatropha seeds (*Lapalapa*). *Electronic J. Enr. Agr. Food Chem,* 2010; 9: 1760-1771.

[29]. Serpil, S and Servet, G. S. *Physical properties of foods.* New York: Springer Science + Business Media, LLC, 2006; pp 1 - 3.

[30]. Eke, C. N. U., Asoegun, S. N. and Nwandikom, G. I. Physical properties of Jack bean (*Canaralia ensiformis*). *Agricultural Engineering International* 2007; 9: 1 - 11.

[31]. Chaudhary, D. A. Engineering properties of biological materials. A technical paper presentation. 2015.

[32]. Singh, B. B. Recent genetic studies in cowpea. In: Fatokun, C. A., Trawali, S. A., Singh, B. B., Kormawa, P. M. & Tamo, M. A. eds. *Challenges and opportunities for enhancing sustainable cowpea production.* Ibadan, Nigeria: International Institute of Tropical Agriculture. 2002; pp. 3-13.

[33]. Vishwarma, R. K., Shivhare, U. S. and Nanda, S. K. Physical properties of guar seeds. *Food and Bioprocess Technology,* 2012; 5: 1364 - 1371.

[34]. Sablami, S. S. and Ramaswamy, H. S. Physical and thermal properties of cereal grains. In: Ragharan, G. S. V., Chakraverty, A., Mujumdar, A. S., & Ramaswany, H. S. eds. *Handbook of Postharvest Technology*. New York: Marcel Dekker Inc. 2013; p. 40.

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

[36]. Tamirat, R. G. Moisture-dependent physical properties of Cardamen (*Electtaria cardamom*) seed. *Agric. Eng. Int. CIGR Journal,* 2012; 14 (2): 118 - 125.

[37]. Wikipedia. *Bulk density.* 2021; Retrieved on 10/05/2021 from https://www.en.m.wikipedia.org/Bulk-density.

[38]. Barbosa-Canovas GV, Juliano P, Peleg M. Engineering properties of Foods: In Food Engineering (ed. Gustavo V. Barbosa-Canovas). Oxford. EOLSS Publishers. 2004.

[39]. Davis, R. M. and Zibokere, D. S. Effect of moisture content on some physical and mechanical properties of cowpea (*Vigna unguicalata L. (Walp). Agricultural Engineering International CIGR Journal,* 2011; 13 (1): 1700 – 1716.

[40]. Haiduc, A. M. and Van Duynhoven J. Correlation of porous and functional properties of food materials by NMR relaxometry and multivariate analysis. *Magn. Reson. Imaging* 2005; 23: 343 - 345.

[41]. Roca E, Guillard V, Guilbert S, Gontard N. Moisture migration in a cereal-composite food at high water activity: Effects of initial porosity and fat content. *J. Cereal Sci.*, 2003; 43: 144 - 151.

[42]. Mohamed, I. S. and Mohamed, I. A. Physical and mechanical properties of Faba bean seeds. *Misr. J. Eng.,* 2010; 23 (2): 437 - 447.

[43]. Kayode , S. E. and Olorunfemi, B. J. Comparison of some physical and mechanical properties of Nigerian local soyabean and cowpea. *Leonardo Electronic Journal of Practices and Technologies,* 2018; 33: 235 - 256.

[44]. Ravikumar, N., Roopa Bai, R. S., Nidoni, U., Ramachandra, C. T., Prakash, K. V. and Sharanagouda, H. Engineering properties of field beans (*Lablab purpureas L.*) at different soaking time. *Int. J. Curr. Microbiol. App. Sci,* 2018; 7 (3): 2024 - 2036.

Amadi, N. V, et. al. Measurement of Engineering Properties of three varieties of Cowpea (Vigna unguiculata L. Walp) seeds.." *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)*, 16(03), (2022): pp 43-51.