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STORAGE METHODS INFLUENCE SOME PHYSICAL AND GRAVIMETRIC PROPERTIES OF JATROPHA (*Jatropha curcas*) SEEDS

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Abstract

Common storage methods and their effects on some engineering properties of Jatropha seeds were studied. Engineering properties of seeds are important in their handling, storage, processing and equipment design. Samples were collected from the Jatropha plantation in the Teaching and Research Farm of the University of Ibadan, Nigeria, populated with Jatropha assessions of age uniformity. Using standard methods, gravimetric properties (like true and bulk densities, porosity) and physical properties (like length, width, thickness, sphericity, surface area) of the seeds were determined for three months of storage at one month interval for crib, refrigerator and room storage methods. Data were analysed using GENSTAT Discovery (Edition 4). Means were separated using Least Significant Difference (LSD) at 5% probability level. The storage methods had no statistical significant effect on the physical properties while gravimetric properties were significantly affected. In the crib method, bulk density decreased (416 - 398 kg/cm^3) and true density increased (709 - 820 kg/m^3) while refrigerator showed increases in bulk (416 to- 432 kg/m^3) and true (709 - 788 kg/m^3) densities. For room method, true and bulk densities increased from 709 to 764 kg/m^3 and 416 to 441 kg/m^3 respectively. Porosity increased in the crib (41.3 – 51.4%), refrigerator (41.3 – 42.2%) and room (41.3 – 41.7%) methods. Therefore drying will be most efficient in crib method because of more pore spaces in the seed bulk. Baseline data of the physical and gravimetric properties of Jatropha curcas seeds required for machine and equipment design was generated.

Key words: *Jatropha, physical property, seed storage, crib, porosity*

INTRODUCTION

Jatropha curcas, commonly called ‘physic nut’, is a deciduous, multipurpose shrub belonging to the family Euphorbiaceae. *Jatropha curcas* L. is the commonest specie found in Nigeria [9] and known as “cinidazugu” and “lapa lapa” in Hausa and Yoruba languages respectively [5]. It is normally a small evergreen, nearly glabrous or soft-wooded shrub of three to four meters in height but can attain a height of eight to ten meters under favorable conditions. The fruit is a capsule of 2.5 to 5.0 cm in diameter; seed is ovoid-oblong and becomes dull brownish black when matured after two to four months of flowering. Five year old plantation of *Jatropha curcas* (J. Curcas) yields 12 tons of seeds per hectare in a year [11], while 0.8-1.0 kg of seeds/meter of live fence can be obtained if it is planted for hedge [10]. J. Curcas seed, leaf and bark have medicinal values. The sap from the leaves can be used on bee or wasp sting. J. Curcas has been used in traditional medicine to cure various infections such as scabies and dermatitis. Researchers had isolated and characterized numerous biologically active compounds from all parts of the plant. J. Curcas plant also has environmental benefits such as a potential enrichment of the soil. Its oil cake is rich in Nitrogen 6%), phosphate (2.75%) and potassium (0.94%) which can be used as organic manure [1]. The oil can also be used to replace synthetic fertilizer by undertaking plantations of J.*curcas* in waste lands [1]. It is also recognized as the most potential plant for biodiesel production, since the seed contains high oil content (30-38%) and can be grown under different land-use situations [6]. It is propagated by seeds or cuttings and bears fruits within two to three years. Also, it can be commercially exploited in four to five years and lasts for about 50 years [7]. The huge plantation has already started and going on across Nigeria. Meeting such large-scale planting targets and raw materials for biodiesel and pharmaceutical production will require a very substantial quantity of seed supply annually, hence the need for effective storage. However, the engineering properties of seeds generally play an important role in the proper handling, storage and processing of the seeds including the design and construction of required machines and equipment. Bulk density, true density and porosity can be useful in sizing grain hoppers and storage facilities. Grain bed with low porosity will have greater resistance to water vapor escape during the drying process, which may lead to higher power to drive the aeration fans. Sphericity of seeds determine how easily the seeds will roll on material surfaces and the shape of apertures on screening equipment while arithmetic and geometric mean diameters help in determining the aperture size. According to [4], a number of important changes in the structure of agricultural materials take place in the course of hydration and they are mainly associated with increased water content. Therefore seeds, when exposed to atmospheric conditions may experience seed moisture changes. This work therefore investigated the likely changes in the physical and gravimetric properties of Jatropha seeds under different storage methods.

MATERIALS AND METHODS

Collection and preparation of sample

Samples were collected from the Jatropha plantation in the Teaching and Research Farm of the University of Ibadan, Oyo State, Nigeria. The Jatropha plantation is populated with Jatropha plants of different accessions with uniformity in age. Matured pods were both picked from the floor (fallen pods) and also plucked from the trees by hand. The pods are in clusters and brown in color indicating its maturity.

Shelling of pods and cleaning of seeds

The pods were split open by hand. There was minimum of one seed and maximum of three seeds per pod. The seeds were collected in a polythene bag and cleaned to remove dirt and remains of broken pods that might have been mistakenly packed together with the seed. The seeds were later distributed into three sample lots.

Storage of seeds: The 3 storage methods employed in this project include: a)Refrigerator, b) Crib and c) Room methods. The seeds were stored in these three ways for three months and data were taken at one month interval. .

Determination of physical properties

***Measurement of seed axial dimension*:** The true axial dimensions of each of 30 randomly selected seeds from each sample lot were measured [22, 15, 20, 4]. The axial dimensions were: length, width and thickness. A Vernier caliper with 0.05 mm accuracy was used for taking the measurements.

***Principal dimensions*:** The principal dimensions are the Arithmetic mean diameter (D_a) and Geometric mean diameter (D_g) dimensions which were calculated according to equations 1 and 2 respectively from the values of the three axial dimensions of each seed.

$$D_a = (L + W + T)/3 \qquad (1)$$

$$D_g = (LWT)^{1/3} \qquad (2)$$

where L = length; W = width; T = thickness in mm [14].

***Surface area*:** The surface area for *Jatropha* seeds was determined by using the analogy of a sphere of the same geometric mean diameter using equation 3

$$S = \pi D_g^2 \qquad (3)$$

where S = surface area, D_g = geometric mean diameter. [17, 19, 2, 12].

Determination of Gravimetric Properties

***Individual seed mass*:** The mass of individual seed was determined by weighing ten seeds and dividing the total mass of the seeds by ten. To cross reference with the above method, the mass of individual seed was also determined by weighing individual seed. This was replicated 5 times.

***True density*:** Seed volume was determined using the liquid displacement method discovered by [14]. The volume of individual seed was determined by pouring 10 g of seeds into 20 ml of toluene (C_7H_8) in a measuring cylinder. The difference between the initial and final level of toluene in the measuring cylinder represented the volume displaced by the seeds which was divided by the number of seeds making up the 10 g to determine the volume of one seed. This was replicated five times. Toluene was used in place of water, because it is absorbed by seeds to a less extent. Also, its surface tension is low and its dissolution power is low [13].

***Thousand Grain mass*:** The mass of a thousand grains was determined by counting randomly selected hundred seeds and weighing them on an electronic balance. The result was multiplied by 10 to obtain the mass for 1,000 seeds. The experiment was replicated five times and the means determined for each sample. [20].

***Bulk density*:** The bulk density is the ratio of the mass of a sample of a seed to total volume [18]. Bulk density for all the samples were determined by filling an empty 320 ml beaker with *Jatropha* seeds and weighed [14]. The weight of the seeds was obtained by displacing the weight of the beaker on an electronic balance while weighing the seed - filled beaker on the balance. To achieve uniformity in bulk density, the beaker was tapped 10 times for the seeds to consolidate [14]. The beaker was filled with seeds dropped from a 15 cm height and a sharp - edged flat was used to remove excess seeds to level the surface at the top of the graduated beaker [15]. Bulk density was calculated using equation 4, given below:

$$\rho_b = m/v \qquad (4)$$

where m = mass of seeds; v = volume of beaker occupied by the seed bulk. This was replicated 5 times [14]

***Porosity*:** Porosity is the ratio of free space between grains to total of bulk grains, determined by

$$P = [(\rho_t - \rho_b) / \rho_t] \times 100 \qquad (5)$$

where P = porosity, ρ_t = true density , ρ_b = bulk density. [8]. This was calculated for each replicate of samples using their respective values of bulk and true densities.

Statistical analysis

Data collected were subjected to analysis of variance using GENSTAT Discovery (edition 4). Means were separated using Least Significant Difference (LSD) at 5% level of probability**.**

RESULTS AND DISCUSSIONS

Physical properties

Analyses of the physical properties of Jatropha seeds for the three storage methods are shown in Tables 1, 2 and 3. Changes in all the physical properties for the methods were not statistically significant (P<0.05) except for significant decrease and increase in seed thickness for crib and room methods respectively within three months of storage.

Table 1. Physical properties of Jatropha seeds at different months in a crib

Month	Length (cm)	width (cm)	thickness (cm)	Arithmetic dimension (cm)	Geometric dimension (cm)	Surface Area (cm^2)	Sphericity
0	1.789	1.099	0.873	1.254	1.196	4.509	0.671
1	1.783	1.092	0.850	1.242	1.183	4.404	0.664
2	1.738	1.101	0.831	1.224	1.167	4.288	0.672
3	1.787	1.105	0.857	1.249	1.191	4.461	0.668
LSD	NS	NS	0.029*	NS	NS	NS	NS

**Significant at p=0.05*
Source: Laboratory work (2018)

The changes in seed thickness may be ascribed to changes in seed moisture caused by changing atmospheric conditions depending also on the seed internal structure or internal cell arrangement. This caused a permanent change in the axial dimensions of the seeds because of the seeds' exposure to the atmosphere.

The refrigerator method had no significant effect on the physical properties of *Jatropha*

seeds therefore the seeds can be stored for three months in the refrigerator without significant change in the seeds' physical properties.
This may be attributed to the 'controlled atmospheric conditions' in the refrigerator. It is one of the values for calculating arithmetic and geometric mean diameters which are used in determining aperture size in the design of screens or separators for seeds.

Table 2. Some physical properties of Jatropha seeds at different months in a refrigerator

Month	Length (cm)	width (cm)	thickness (cm)	Arithmetic dimension (cm)	Geometric dimension (cm)	Surface Area (cm^2)	Sphericity
0	1.789	1.099	0.873	1.254	1.196	4.509	0.671
1	1.812	1.105	0.856	1.257	1.196	4.500	0.661
2	1.829	1.119	0.879	1.276	1.216	4.647	0.665
3	1.811	1.112	0.852	1.258	1.196	4.504	0.661
LSD	NS	NS	NS	NS	NS	NS	NS

**Significant at p=0.05*
Source: Laboratory work (2018)

Table 3. Some physical properties of Jatropha seeds at different months stored at room temperature

Month	Length (mm)	width (mm)	thickness (mm)	Arithmetic dimension (mm)	Geometric dimension (mm)	Surface area (mm^2)	Sphericity
0	1.789	1.099	0.873	1.254	1.196	4.509	0.671
1	1.811	1.128	0.852	1.264	1.203	4.552	0.665
2	1.767	1.109	0.835	1.237	1.178	4.368	0.668
3	1.820	1.114	0.874	1.269	1.209	4.602	0.665
LSD	NS	NS	0.027*	NS	NS	NS	NS

**Significant at p=0.05*
Source: Laboratory work (2018)

The graph (Fig. 1) shows the non-linear trend in the effect of Crib and Room storage methods on the seed thickness of Jatropha. The equations generated can be used to predict the value of seed thickness at any time of storage.

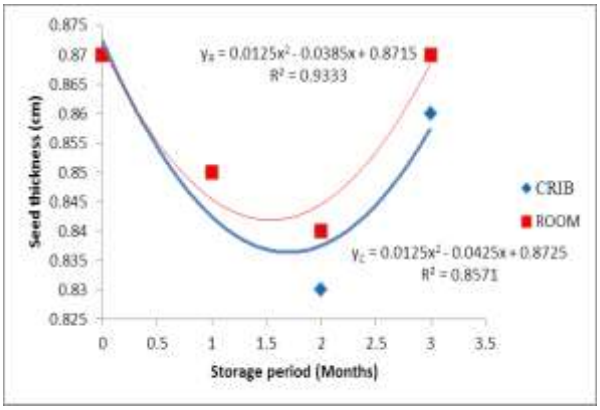

Fig. 1. Graph showing effect of Crib and Room storage methods on seed thickness.
Source: Laboratory work, 2018.

$$Y_{Crib} = 0.0125x^2 - 0.0425x + 0.8725 \quad R^2 = 0.8571 \qquad (6)$$

$$Y_{Room} = 0.0125x^2 - 0.0385x + 0.8715 \quad R^2 = 0.9333 \qquad (7)$$

Gravimetric properties

Tables 4, 5 and 6 show the significant effects of storage methods on porosity, bulk and true densities of Jatropha seeds. In the crib method, true density increased while bulk density decreased significantly (P<0.05) in three months. Both properties also significantly increased in room and refrigerator storage methods. Decrease in either bulk or true density implies that the rate of increase in mass of the seed bulk is lower than the corresponding volumetric expansion rate of the seed bulk [16]. And increase in either bulk or true density implies that the rate of increase in the mass of the seed bulk is higher than that of the volume it occupies. Increase or decrease in bulk and true densities is due to structural properties of the seed [13]. Similar decreasing trend in bulk density was reported by [21] for pea seed, [3] for some legume seeds, and [16] for Karanja kernel. The knowledge of bulk and true densities of Jatropha seeds is important in the design of and the choice of material for its storage and packaging equipment. Fig. 3 and 4 show the polynomial and linear trends in the storage effects on true and bulk densities of Jatropha seeds. The equations generated can be used to determine the value of the densities and porosity at any point of storage (Fig. 2, 3 and 4). Porosity increased linearly in crib (41.33 – 54.41%), and increased (41.33 – 42.17%) in both room and refrigerator methods significantly (P<0.05) in a second order polynomial trend (Fig. 2). Highest value of porosity was recorded in crib method while room and refrigerator methods had similar values. This implies that influence of changing atmospheric conditions was more severe in crib method where Jatropha seeds were fully exposed to the atmosphere, limited in room method and controlled in refrigerator method. Porosity depends on bulk and true densities, hence the variation in porosity [13]. It describes the ratio of pore spaces in a grain bulk to the space occupied by the whole grain mass. This means that increase and decrease in porosity result in high and low magnitude of pore spaces respectively in a grain mass. Porosity is an essential characteristic used in determining the rate of aeration, cooling, drying, heating and the design of heat exchangers and packaging equipment. High porosity encourages faster rate of drying or cooling because of free air flow within the seed bulk which also discourages spoilage during storage. Irrespective of the storage method or period of storage, other gravimetric properties of Jatropha seeds did not have a significant difference.

Table 4. Some gravimetric properties of Jatropha seeds at different months in a crib

Month	Individual seed weight(g)	10 seeds weight (g)	1000 unit mass (g)	True density (kg/m^3)	Bulk density (kg/m^3)	Porosity (%)
0	0.802	6.99	657.2	709	416	41.33
1	0.650	7.04	668.4	814	415	48.97
2	0.760	7.06	678.2	788	409	48.07
3	0.704	6.86	662.5	820	398	51.41
LSD	NS	NS	NS	0.027*	0.008*	2.020*

**Significant at p=0.05*
Source: Laboratory work (2018)

Table 5. Some gravimetric properties of Jatropha seeds at different months stored in a refrigerator

Month	Individual seed weight(g)	10 seeds weight (g)	1000 unit mass (g)	True density (kg/m^3)	Bulk density (kg/m^3)	Porosity (%)
0	0.802	7.00	657.2	709	416	41.33
1	0.720	6.57	647.7	714	439	38.59
2	0.656	6.60	639.7	769	444	41.65
3	0.682	6.74	642.5	788	432	42.17
LSD	NS	NS	NS	0.021*	0.008*	1.418*

*Significant at p=0.05
Source: Laboratory work (2018)

Table 6. Some gravimetric properties of Jatropha seeds at different months stored in a room

Month	Individual seed weight (g)	10 seeds weight(g)	1000 unit mass (g)	True density (kg/m^3)	Bulk density (kg/m^3)	porosity (%)
0	0.802	7.00	657.2	709	416	41.33
1	0.638	6.60	678.7	769	438	43.02
2	0.720	6.98	671.8	769	449	41.65
3	0.808	6.98	664.8	764	441	42.17
LSD	NS	NS	NS	0.018*	0.009*	1.832*

**Significant at p=0.05*
Source: Laboratory work (2018)

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After three months of storing *Jatropha*, the physical appearance of the seeds stored in the refrigerator and room temperature maintained their physical appearance over the period of storage (Plates 2 and 3). This is probably because of the controlled and limited atmospheric conditions in the refrigerator and room methods respectively. Appearance of seeds stored in crib changed after three months of storage and attacked by insects (Plate 1).

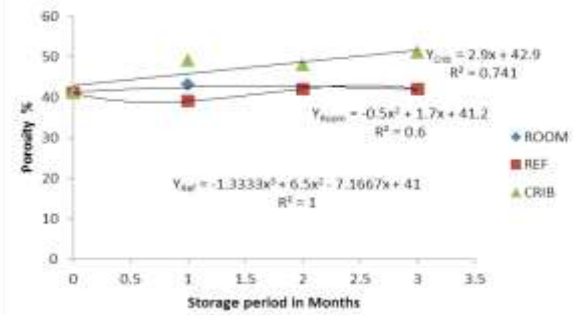

Fig. 2 Graph showing the effects of the storage methods on the porosity of *Jatropha* seeds.
Source: Laboratory work 2018.

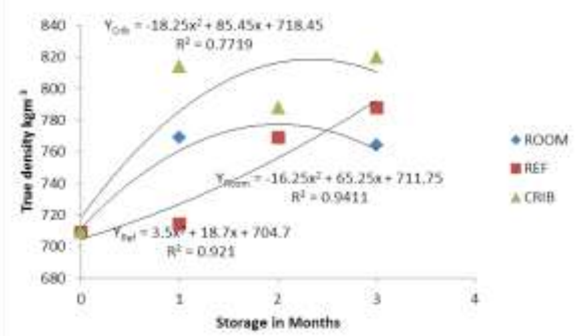

Fig. 3 Graph showing the effects of the storage methods on the True density of *Jatropha* seeds
Source: Laboratory work 2018.

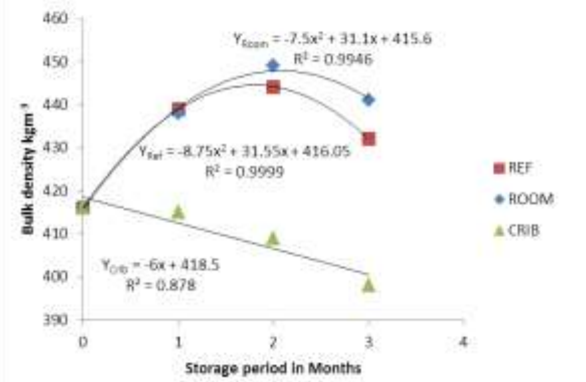

Fig. 4 Graph showing effects of storage methods on the Bulk density of *Jatropha* seeds
Source: Laboratory work 2018.

Photo 1. *Jatropha curcas* seeds stored in crib after three months
Source: Laboratory work 2018.

Photo 2. *Jatropha curcas* seeds stored in room temperature after three months
Source: Laboratory work 2018.

Photo 3. *Jatropha curcas* seeds stored in refrigerator after three months
Source: Laboratory work 2018.

CONCLUSIONS

The following conclusions were drawn from the study:
-Changes in the physical properties of *J. Curcas* seeds like seed dimensions, sphericity and surface area due to storage methods studied were not statistically significant.
-*J. Curcas* seeds showed statistical significant differences in their gravimetric properties when subjected to different storage methods.
-Equations were generated to predict the behavior of *J. Curcas* seeds under the different storage methods.

-Some of the data necessary for the design of equipment for handling, storing and packaging of *Jatropha* seeds were developed.

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