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Note

Physical properties of Mexican sunflower seed

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A b s t r a c t. Studies were conducted on some physical properties of Mexican sunflower at 9.68% moisture level using standard methods. The geometric dimensions were found to be within the range for most grass seed and cereals. The low sphericity and bulk density, as a result of the flattish shape of the seed, confirmed that the seeds are expected to slide rather than roll in handling. The low porosity and terminal velocity indicate that the free air flow during drying, aeration and pneumatic separation may be difficult, however, these are useful in separation of the seed from heavier materials such as stone and pebbles.

K e y w o r d s: Mexican sunflower, physical properties, thermal properties

INTRODUCTION

The sunflower family (*Asteraceae* and *Compositae*), a ubiquitous family, is the largest family of flowering plant containing nearly 1 550 general and 24 000 species. It is rivalled in size only by the orchid family (*Orchidaceae*) with about 20 000 species. Mexican sunflower, *Tithonia diversifolia* (*Asteraceae*), is native to North America, but was introduced to West Africa for ornamental purposes (Akobundu and Agyakwa, 1998). It was also reportedly cultivated for the same reason in India. It has now become a problem weed of field crop, wasteland and roadside, especially in SW Nigeria (Smith and Anisu, 1997). Ayeni *et al*. (1997) also revealed, from a reconnaissance survey on the occurrence of *Tithonia diversifolia* in SW Nigeria, carried out along the major highways linking Ibadan to other major towns in SW Nigeria, that the plant is prominent in this part of the country which is mainly a rain forest and savannah zone.

Tithonia diversifolia has a wide range of applications, not only in the agricultural sector, but also in pharmaceutical sectors, among others. Liasu and Atayese (1999) considered it as being potentially useful for land fallow management due to its fast growing habit that puts it at an advantage over most other weeds which were eventually overpowered when growing together. Liasu and Ogunkunle (2007) postulates that the wood of older stems may have a potential application in wood based industries for making pulps and paper, match splint and tooth picks, while the bark could be found useful in carpet weaving. Ajaiyeoba *et al*. (2005) established that crude extraction of its leaves has intrinsic anti-malaria properties as the plant is rich in quinine, hence the local name in Yoruba language 'sépèfúnbá' (curse on malaria). Sunflower seed is a source of edible oil also used for making soap and paint, while its oil cake is used in livestock feed, fertilizer, shortening cooking, salad oil and margarine. The seed has the potential for large scale production of oil and biodiesel due to its abundance, though not reported in any literature. The lack of information on this crop is a result of the fact that it is currently considered as a weed.

Investigations on the process of engaging in large scale indigenous production of this species of plant, high commercial exploitation, variation in its characteristics from place to place, and physical attributes of its seeds, are necessary to derive the benefits. These are important in solving many problems associated with the design of handling and processing machines and analysis of the behaviour of the product, thus serving as a database for machine designer. The dearth of information on this seed requires that appropriate research work to produce the information useful in design and handling equipment must be embarked upon.

The objective of this study was, therefore, to determine physical properties of Mexican sunflower seed at harvest moisture level with a view to obtaining information useful in machine design for processing and handling.

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MATERIAL AND METHODS

The seed was collected from different fields at Ibadan, Oyo State in Nigeria, at the time of maturity. Threshing was done manually with the method related to that described by Simonyan and Eke (2009). This involved cutting the heads of matured sunflower with scissors or a knife into bags, and then beating strenuously until the seeds are separated completely from the chaff. The seed and chaff were then gathered together and hand winnowed with tray after sieving with a small shallow basket. Further cleaning was done by hand picking to get rid of other impurities.

Seed to chaff ratio was calculated using the NCAM (1998) relation, as the ratio of the mass of dry seed to the mass of dry chaff. The seed moisture content (MC) was determined by a low constant temperature oven drying method (ISTA, 2009; ASAE, 2003). The method is good for species that are rich in oil or volatile substances. The seed dimensions in the three perpendicular axes were determined by selecting one hundred seed randomly, and the three linear dimensions of each seed, namely major (a), intermediate (b) and minor (c) diameters were measured with a digital micrometer screw gauge and the mean values were reported. The geometric mean diameter for each replication was computed from a, b, and c. The sphericity for each seed was calculated as the ratio of the geometric mean diameter to the major diameter. The bulk density was determined using the mass by volume relationship. The volume was determined by the water displacement method and the true density, defined as the ratio of the given mass of a matter to its volume, was calculated. The porosity was calculated from the value obtained for bulk density and true density. The effective seed diameter was computed according to Shepherd and Bhardwad (1986).

The coefficient of static friction was determined on five structural materials, namely mild steel sheet, stainless steel sheet, glass surface, plywood with polythene cover and plywood surface, using an inclined plane apparatus. The dynamic angle of repose was determined according to Razavi and Milani (2006). The terminal velocities for seed, kernel and hull were determined using a vertical wind tunnel. Specific heat capacity of the seed was determined in an adiabatic copper calorimeter, for five replications, using the method of mixture.

RESULTS AND DISCUSSION

The average moisture content obtained is 9.7% and this serves as the moisture level at harvest when the seed is allowed to dry on the field, hence the basis at which all parameters were measured.

The seed-chaff ratio was found to be 1:1.13. Seed-chaff ratio is the ratio of the clean seeds obtained from harvested heads of matured Mexican sunflower after threshing to the chaff. This is useful in estimating the yield of seeds per quantity of heads harvested. However, the method of threshing adopted, the growth condition, time of harvesting, moisture level at harvest, among other field and harvesting losses, may result in variation of this value. Meanwhile, plant rhythm growth ability that coincides with the season will encourage the use of processing machinery and result in reduced losses.

The results of all the parameters measured, showing the number of observations (N), mean, standard deviation (SD) and range of values are presented in Table 1.

The shape of Mexican sunflower seed is conical. It is tapered and pointed at the base, and appears four-sided in cross-section. The major, intermediate and minor diameters range from 4.67 to 7.10, 1.70-2.70, and 0.94-1.66 mm, with means of 5.94, 2.21 and 1.33 mm, respectively. These are higher than 2.98-3.66, 1.86-2.24 and 1.70-2.01mm for pearl millet variety (Jain and Bail, 1997) but almost the same in breadth and thickness. It falls within the same range of size: 4.27-4.65, 2.22-2.38 and 0.85-0.88 mm at 6.09-16.81%

Table 1. Physical properties of Mexican flower seed

Parameters	Number of replicates	Mean	SD	Range
Moisture conten (% w.b.)	5	9.68	0.10	9.55-9.76
Major diameter (mm)	100	5.94	0.52	4.67-7.10
Intermediate diameter (mm)	100	2.21	0.22	1.70-2.70
Minor diameter (mm)	100	1.33	0.15	0.94-1.66
Geometric mean diameter (mm)	100	2.59	0.19	2.09-3.10
Sphericity (%)	100	43.72	3.47	37.57-52.80
1 000 seeds mass (g)	20	6.79	0.07	6.60-6.92
Bulk density (kg m^{-3})	20	350.06	7.11	340.59-363.51
True density (kg m^{-3})	20	933.06	121.34	769.23-1 111.00
Porosity (%)	20	61.75	5.31	52.74-69.70
Effective seed diameter (mm)	20	2.40		2.38-2.42

(MC d.b.) reported for flax seed (Yalcin and Ersan, 2007), and is slightly smaller than guna seed with 8.08, 5.27, and 2.04 mm at 4.7% (MC d.b.) (Aviara *et al*., 1999). It is smaller than sorrel seed (Omobuwajo *et al*., 2000) but nearly the same range in major axis, much smaller than gram, African bread fruit and oil bean seed (Omobuwajo *et al*., 1999).

The geometric mean diameter had an average value of 2.59 mm, with 0.19 mm as standard deviation. It was observed that geometric mean diameter increased with an increase in seed size, resulting in the seed with the smallest minor diameter having the least geometric diameter. Geometric mean of axial dimension is useful in defining the characteristics of the dimensions for irregular solids (Henderson and Pabis, 1962). It is also useful in estimation of projected area of particles moving in turbulent or near turbulent region of airstreams, especially with respect to ease of separating extraneous materials from the seed during cleaning by pneumatic means.

The mean sphericity was found to be 43.7%, with a standard deviation of 3.47. The observation follows the same trend as that of Aseogwu *et al*. (2006) that sphericity increases with decrease in seed size, with the small size seed having the highest sphericity. The observed sphericity varied from 37.7 to 52.8% and was found to be within the range of 52.3% reported for African oil bean seed (Oje and Ugbor, 1991) and lower than the value reported for sorrel seed and groundnut. It is much smaller than the value reported for gram seed. The shape of Tithonia seed is irregular and flattish, with the minor diameter about 22% of the major diameter. This low value of sphericity confirmed that the seeds are expected to slide rather than roll.

One thousand grain mass, a property required in characterising the seed and in estimation of the unit mass of the seed, was 6.79 g and the mean value compared with that of sorrel of 36 g (Omobuwajo *et al*., 2000), flax seed of 4.79-5.32 g, groundnut of 500-800 g, and guna of 41 g (Aviara *et al*., 1999). Thus, it outweighed flaxseed and was lighter than the other listed seeds.

Bulk density ranged from 340.59-363.51 kg m^{-3}. The value, when compared with that of sorrel of 637 kg m^{-3} (Omobuwajo *et al*., 2000), flax seed of 555.6 - 726.6 kg m^{-3} (Yalcin and Ersan, 2007), bambara groundnut seed of 696-795 kg m^{-3} and guna seed of 400-544 kg m^{-3} (Aviara *et al*., 1999), is relatively low. This may be due to the smaller size and flattish shape of the seed.

True density ranged from 769.23 to 1 111.00 kg m^{-3}, with mean of 933.06 kg m^{-3}, thus the value is within the same range as 979 kg m^{-3} reported for African bread fruit, 1 000 to 1 111 kg m^{-3} for flax seed (Yalcin and Ersau, 2007) and 680-870 kg m^{-3} for guna seed, but smaller than 111.71 kg m^{-3} for sorrel seed (Omobuwajo *et al*., 2000), 1 578-1 623 kg m^{-3} for pearl millet seed, 1 257-1 311 kg m^{-3} for gram seed, 1 120 kg m^{-3} for oil bean seed (Oje and Ugbor, 1991) and 1 285 to 1 160 kg m^{-3} for bambara groundnut.

The porosity shows the relationship between bulk and true density and the extent of pore space in the seed mass. The average value obtained was 61.8%. This is higher than that of sorrel seed, flax seed, bambara groundnut seed and guna seed.

Table 2 presents the frictional attributes, which include the coefficient of static friction and the dynamic angle of repose, with respect to five listed structural surfaces.

The values of the coefficient of static friction were 0.20 on glass, 0.31 on stainless, 0.43 on mild steel, 0.31 on plywood with polythene cover, and 0.39 on plywood surface. These differences on the various surfaces will help in selecting materials for the design of parts needed during the construction of inlet and outlet ports for seed and products during processing operations such as threshing, oil expression, *etc*.

The dynamic angle of repose is an engineering property of granular materials. It is the maximum angle of stable slope determined by friction, cohesion and shapes of the particles. Its values were 23.13° on glass, 24.38° on stainless, 28.62° on mild steel, 25.28° on plywood with polythene cover and 27.12° on plywood surface.

Terminal velocity of 2.56, 1.62 and 1.09 m s^{-1} obtained for the seed, kernel and hull are presented in Table 3. The results follow the same trend as other seeds with terminal velocity of the hull being lower than those of the kernel and the seed. The differences were, however, not appreciable, indicating that the pneumatic separation may be difficult to achieve.

T a b l e 2. Frictional characteristics of the seed (mean for 20 replicates)

Characteristics	Mean value	SD	Range
	Coefficient of static friction		
Glass	0.20	0.02	0.18-0.24
Stainless	0.31	0.02	0.30-0.33
Mild steel	0.43	0.04	0.36-0.49
Plywood with polythene cover	0.31	0.01	0.29-0.32
Plywood surface	0.39	0.02	0.33-0.42
	Angle of repose		
Glass	23.13	0.78	22.28-24.30
Stainless	24.38	0.49	23.50-24.31
Mild steel	28.62	1.62	26.24-32.01
Plywood with polythene cover	25.28	0.46	24.44-6.08
Plywood surface	27.12	1.44	24.87-30.47

T a b l e 3. Terminal velocity and specific heat capacity at 80°C of the investigated materials (mean for 20 replicates)

Medium	Mean value	SD	Range
Terminal velocity (m s^{-1})			
Seed	2.56	0.21	2.25-2.90
Kernel	1.62	0.38	1.30-2.25
Hull	1.09	0.23	0.84-1.30
Specific heat capacity (kJ kg^{-1} K^{-1})			
Seed	4.57	0.60	3.48-5.32

The specific heat capacity of seed at 80°C was found to vary from 3.48 to 5.32 kJ kg^{-1} K^{-1} (Table 3). The value is within the range reported for various varieties of oil bean seed and higher than that of sorrel.

CONCLUSIONS

1. The average dimensions for each of the three principal diameters (major, intermediate and minor) and the 1 000 grain mass were 5.94, 2.21, 1.33 mm and 6.79 g, respectively.

2. The geometric mean diameter, sphericity and effective seed diameter obtained were 2.95 mm, 43.72% and 2.40 mm, respectively.

3. The coefficient of static friction varied from 0.20 to 0.43 on five different structural materials that included glass surface, stainless surface, mild steel surface, plywood with polythene cover surface and plywood surface.

4. The dynamic angle of repose varied from 28.62 to 33.13 on the aforementioned surfaces.

5. The terminal velocity values of 2.56, 1.62, 1.09 m s^{-1} were observed for the seed, kernel and hull, respectively.

6. The specific heat capacity at 80°C varied from 3.48 to 5.32 kJ kg^{-1} K^{-1}.

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