DESIGN RELATED PHYSICAL PROPERTIES OF SNAKE TOMATO SEEDS

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ABSTRACT

This paper gives an overview of design related physical properties of snake tomato seeds found in the South West of Nigeria. The seed length, width, thickness, geometric mean diameter, sphericity, one thousand seed mass, surface area, unit and bulk volume, true and bulk density, specific surface area, porosity, static angle of repose, and coefficient of static friction were investigated at 16.56 % moisture content dry basis. The results obtained range from 12.73 – 14.65 mm, 7.18 – 8.36 mm, 4.54 – 5.59 mm and 7.56 – 8.55 mm for length, width, thickness and geometric mean diameter, respectively. The unit and bulk volume, true and bulk density were found to be in the range of 24.00 – 30.00 cm^3 and 42.00 – 48.00 cm^3, 0.67 – 0.80 g cm^{-3} and 0.42– 0.46 g cm^{-3}, respectively. The seed porosity, sphericity, and one thousand seed mass were in the range of 36.96 – 42.86 %, 56.41 – 63.93 % and 192.10 – 202.10 g, respectively. Surface area, specific surface area and static angle of repose investigated were in the range of 1.80 – 2.30 cm^2, 6.89 – 8.71 cm^2 cm^{-3}, and 30.96 – 36.19 ^{0}, respectively. The coefficient of static friction against the surfaces; steel sheet, plywood, rubber, and aluminium revealed that they were in the ranges of 0.41 – 0.52, 0.68 – 0.81, 0.59 – 0.75, and 0.47 – 0.61, respectively. Plywood offered the highest coefficient of static friction while steel sheet gave the least value. The results of this investigation is aimed to provide the necessary data base for design engineers to make its seed planting and the seed extraction mechanized.

Keywords: Snake tomato seed (STS), axial dimension, density, porosity, specific surface area

INTRODUCTION

Snake tomato (*Trichosanthes cucumerina Linn)* is a well known plant, the fruit of which is mainly consumed as a vegetable. It is generally believed to have been domesticated in India from the wild species still found in India and other parts of Southeast Asia and Australia. Presently, snake tomato is cultivated principally in India and parts of Southeast Asia, but it also occurs in Australia, West Africa, Latin America, and the Caribbean (ECHO, 2006). *T. cucumerina* is a monoecious plant, having both male and female reproductive organs in the same plant. It has tendrils, a slender stem-like structure by which it attaches itself to an object for support. It is an annual climber belonging to the family Cucurbitaceae [Sandhya *et al.,* 2010]. Supports for its tendrils are made 1–1.5 m above the ground using horizontal bamboos and poles, thatched roof tops, over walls or fences. The provision of raised platform allows the fruits to hang down and prevent them from torching the ground that can cause their rotting. The fruits can reach a length of 30 – 60 cm (ECHO, 2006) with diameter of 5–7 cm.

It is commonly called as Snake Gourd, Viper Gourd, Serpent Vegetable, English Tomato, Long Tomato, and Tomato Elejo. Snake tomato derives its name from the snake-like shape of the fruit. It is locally grown as a vegetable in home gardens in Africa (Soladoye & Adebisi,

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2004). Harvesting of the fruits starts 3 – 4 months after sowing. The fruits are very slender, long and cylindrical berry, light green coloured at unripe (immature) stage, and red coloured when (ripe) matured. A stand of *T. cucumerina* can produce up to 150 fruits. Snake tomatoes do not keep well after harvest; they can be stored unprocessed for less than 5 days for the ripe ones.*T. cucumerina* is an under-exploited fruit vegetable in Nigeria in the past but it is now gaining attention in South West of Nigeria. In South West of Nigeria, it is found growing in protected environments in backyards (Adebooye *et al.,* 2004). Snake tomato fruit is usually consumed as a vegetable due to its good nutritional value. The fruit pulp is a good source of ascorbic acid, and low anti-nutritional oxalate composition [Adebooye *et al.,* 2005; Adebooye & Oloyede 2005]. The fruit is capable of expelling worms, and anti-diabetic in nature (Devendra *et al.,* 2010). Snake tomato (*T. cucumerina*) fruit pulp is used as substitute or complement for the regulartomato (*L. esculentum*) especially during the period of regular tomato scarcity and its attendant exorbitant prices (Onagoruwa, 2002). The pulp of *T. cucumerina* is sweet tasting, aromatic, deep red in colour and does not go sour as quickly as paste of *L. esculentum* (debooye *et al.,* 2005; Adebooye & Oloyede, 2006).

Tomato is one of the basic essentials to so many meals used in various dietary formulations in Nigeria because of its high nutritive value. It is a source of Vitamin C and a significant source of Vitamins A and B (Robinson, 1977). Despite the popularity of regular tomato (*Lycopersiconesculentum*), its total production in South West of Nigeria is grossly inadequate. Adeoye *et al.* (2009) reported that most of tomato traded in South West Nigeria markets were sourced from Northern part of Nigeria. It is evidence that production of tomato in South West Nigeria is below the consumption requirements. This can be attributed to the fact that it is cultivated by peasant farmers whereas its supply needs to meet up daily consumption requirements of the teeming population. The inadequacy can also be attributed to the seasonality of the product. In view of the growing demand for tomato in South West of Nigeria, introducing and planting another species of tomato as compliment to the existing one would be a logical means to meet up with the demand. Snake tomato can grow throughout the year except in extreme winter (Akinyemi *et al.,* 2012). This plant has the ability to produce large quantity of tomato round the year; this will not only increases the trend to meet up with the demand but also increases the seasonal availability of the product. In view of this, cultivation of snake tomato is in increasing trend. Tomatoes are easily perishable and characterized with short shelf life; therefore they should be processed after harvesting to prolong the shelf life. The pre-process is sorting, washing, and grinding as for regular tomato, but for the snake tomato; sorting, washing, seed extraction, and grinding. The extraction of seeds is the most tedious pre-process in its processing. It is characterized with time consuming, labour intensive, fatigue, and undue force exertion on thumb and the index finger since the seeds have to be extracted and picked one by one. The undue force that is exerted on the fingers, if it continues for prolonged time will cause overload, fatigue, and injury on the forearm, wrist and hand. With not less than 1,200 seeds to be extracted in 20 fruits, one can imagine what it translates to; in time and labour if 1,000 fruits should be processed. In light of this, if increase in cultivation of snake tomato should be encouraged, seeds extraction from its fruits should be mechanized.

Thus, for South West of Nigeria to flourish in snake tomato production there is the need to mechanize seeds extraction from its fruits. The good food value of this plant is an indicator that its cultivation and utilization should be promoted. Two outstanding features of snake tomato seeds (STSs) have been reported as ability to expel/destroy parasitic worms, and with anti-fever property (Nadakarni, 2005). These two attributes of STSs make them a vital raw material in pharmaceutical industry. Presently, there is no information in the literature on the STSs characteristics and physical properties. However, precise knowledge of design related physical properties of STSs should be determined for the mechanization of its planting and seed extraction from the fruits. The objective of this study is to investigate design related physical properties of snake tomato seeds (STSs) found in South West of Nigeria. When these properties are available, mechanization of its planting and seed extraction from the fruits will be at ease.

MATERIALS AND METHODS

Sample Preparation

The study was carried out in 2012 at the Processing Laboratory of Agricultural Engineering Department, Ahmadu Bello University, Zaria, Nigeria. Ripe matured fruits of snake tomato were procured from Ejigbo, Osun State, Nigeria. The fruits were washed with water and later sliced into two longitudinally to access the seeds. The seeds were extracted from the red pulp that coated them by using thumb and the index finger to press the pulp. The extracted seeds were washed and air-dried for 12 hours. Before the determination of its physical properties, immature seeds were removed. The initial moisture content of the seeds was determined by oven-dry method. Plates 1, 2, and 3 show the snake tomato fruits, the fruit's pulp, and it seeds, respectively.

Plate 1: Snake tomato fruits

Plate 2: Snake tomato fruit pulp with seeds

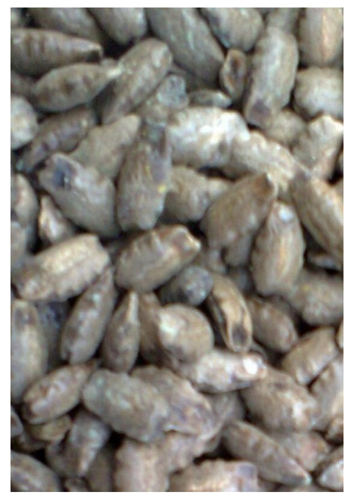

Plate 3: Snake tomato seeds

Size and Shape

Onehundred seeds of snake tomato were randomly selected for size and shape determination. The seed size in terms of axial dimensions, that is length (L), width (W) and thickness (T) were measured using vernier calliper with an accuracy of 0.01 mm. The geometric mean diameter and shape in term of sphericity were determined using relationship given by Mohsenin (1980):

$$D_g = (LWT)^{1/3} \quad \text{.......} \quad (1)$$

$$S = \frac{D_g}{L} \times 100 \quad \text{.......} \quad (2)$$

Where D_g = Geometric mean diameter [mm]

S = Sphericity [%]

Unit Volume, Bulk Volume, Weight, Density and Porosity

Unit volume was determined using fluid displacement technique. Toluene displacement method in calibrated cylinder (Borosilicate 250 ± 1 ml) was used. The volume of the displaced toluene (C_6H_7) by STSs (100 seeds) was recorded as volume of the seeds. The Bulk volume for 100 seeds was determined by filling an empty 250 ml graduated cylinder with the seed [Mohsenin, 1980]. The graduated cylinder was tapped 10 times for seeds consolidation; this was to achieve uniformity in bulk volume. The process was replicated ten times and the volume for each replication was recorded as the bulk volume.

One thousand seed weight was determined by using a digital electric balance with 0.01g sensitivity. This was determined by taking 100 seeds of snake tomato randomly and weighed; the weight was then multiplied by ten to have one thousand seed weight (Nalladulai*et al.,* 2002; Sirisomboon *et al.,* 2007). Ten replicates were used, the mean value was obtained.

For True and Bulk densities determination, the relationships given by Mohsenin (1980) were used.

$$\rho_t = \frac{M}{V_u} \quad \ldots\ldots (3)$$

$$\rho_b = \frac{M}{V_b} \quad \ldots\ldots (4)$$

Where ρ_t = True or solid density [g cm^{-3}]

M = Mass of seed [g]

V_U = Unit volume of seed [cm^3]

ρ_b = Bulk density [g cm^{-3}]

V_b = Bulk volume of seed [cm^3]

Porosity (P) was determined according to relationship given by Mohsenin [1980]:

$$P = \frac{\rho_t - \rho_b}{\rho_t} \times 100 \quad [\%] \quad \ldots\ldots (5)$$

Surface area and Specific surface area: The Surface area of the seed was calculated from the relationship given by Baryeh [2001]; Altuntas *et al.* [2005]; Dash *et al.* [2008].

$$A = \pi D_g^2 \quad \ldots\ldots (6)$$

Where A = Surface area [cm^2]

Specific surface area was determined using relationship given by Mohsenin [1980]:

$$A_s = \frac{\pi D_g^2}{V_u} \quad \ldots\ldots (7)$$

Where A_s =Specific surface area [cm^2 cm^{-3}]

Static angle of repose and Coefficient of static friction: The static angle of repose was determined using the procedure described by Mohsenin (1980); Garnayak *et al.* (2008). A hollow open-ended PVC pipe (50 mm diameter, 150 mm height) was used and then applying trigonometry rules. The pipe was placed over a plain surface and STSs were filled in. The pipe was raised slowly allowing the seeds to flow down and form a natural cone. The height of the cone was recorded by using a moveable pointer fixed on a stand having a span and precision of 150 mm and 1 mm, respectively. The static angle of repose was calculated from the height and diameter of the pile as:

$$\theta_s = \tan^{-1}\left(\frac{2H}{D}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

Where θ_s = Static angle of repose [^{0}]

H = Height of pile [mm]

D = Diameter of pile [mm]

The coefficient of static friction of STSs against four different surfaces (steel sheet, ply wood, rubber and aluminium) was determined. A wooden frame (10cm x 10cm x 6cm) without base and lid was placed over different plain surfaces and filled with seeds. The filled frame was pulled along the surface and the peak force required to start motion was recorded by a fixed spring scale (ESAL 500 ± 5g). Coefficient of static friction was determined using relationship given by Bahnasawy (2007):

$$\mu = \frac{F_T - F_E}{W} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

Whereμ = Coefficient of static friction

F_T = Force required to start motion of filled frame [N]

F_E = Force required to start motion of empty wooden frame [N]

W = Weight of the seeds [N]

Statistical Analysis

The data obtained were subjected to descriptive statistic such as mean, standard deviation and coefficient of variation.

RESULTS AND DISCUSSION

Table 1 shows the summary of the results for the Design Related Physical Properties of Snake Tomato (*Trichosanthes cucumerina*) Seeds at 16.56 % moisture content on dry basis. Judging by acceptance range of coefficient of variation (CV) given as ≤ 14% by Isiaka *et al.* [2006], it can be deduced that the variations that exist in the replications of the experiment are negligible. Therefore, the experimental errors were within the acceptable level.

It is of opinion that data from this investigation will be useful in the design and development of appropriate simple machines for STSs extraction, handling and processing.

Size and Shape

The axial dimensions (Length, Width, and Thickness) of *T. cucumerina* seeds vary in the ranges of 12.73–14.65 mm, 7.18–8.36 mm, and 4.54–5.59 mm, respectively. The corresponding values for Simon cultivar of dent corn seeds at 16.68 % db were 10.82 mm, 7.64 mm, and 4.85 mm, respectively (Ismail *et al.,* 2011). The mean values of axial dimensions reported for red cultivar of watermelon seeds at 4.75 % wb were 18.97 mm, 10.72 mm, and 2.99 mm, (Seyed *et al.,* 2006) respectively.

Figure 1a, 1b, and 1c presents the size distribution curve of STSs. The highest frequency was within 13.49 – 13.87 mm for length, 7.66 – 7.90 mm for width, and 4.76 – 4.98 mm for thickness. Within this range, 37 %, 33 %, and 38 % of STSs were present, respectively.

This range of axial dimensions should be given priority in the design and development of appropriate machines for STSs extraction, handling and its processing.

Table 1. Physical properties of Snake tomato seed at 16.56 % Moisture Content on dry basis

Physical Property	*Unit*	*No. of Observation*	*Mean Value*	*Min. Value*	*Max. Value*	*SD*	*CV*
Length, L	mm	100	13.80	12.73	14.65	0.43	1.35
Width, W	mm	100	7.72	7.18	8.36	0.29	1.09
Thickness, T	mm	100	5.07	4.54	5.59	0.18	0.62
Geometric mean diameter, D_g	mm	100	8.14	7.56	8.55	0.20	0.49
Sphericity, S	%	100	59.00	56.41	63.93	1.35	3.09
1000 Mass, M	g	10	197.61	192.10	202.10	3.13	4.95
Surface area, A	cm^2	10	2.08	1.80	2.30	0.10	0.50
Unit volume, V_u	cm^3	10	27.20	24.00	30.00	1.81	12.09
Bulk volume, V_b	cm^3	10	45.20	42.00	48.00	2.15	10.23
True density, ρ_t	$g\ cm^{-3}$	10	0.73	0.67	0.80	0.04	0.21
Bulk density, ρ_b	$g\ cm^{-3}$	10	0.44	0.42	0.46	0.02	0.05
Specific surface area, A_s	$cm^2\ cm^{-3}$	10	7.69	6.89	8.71	0.56	4.04
Porosity, P	%	10	39.85	36.96	42.86	2.09	10.95
Static Angle of Repose, θ_s	degree	10	33.24	30.96	36.19	1.52	6.95
Coefficient of Static friction, μ							
Steel sheet	value	5	0.47	0.41	0.52	0.04	0.40
Plywood	value	5	0.75	0.68	0.81	0.05	0.35
Rubber	value	5	0.68	0.59	0.75	0.06	0.54
Aluminium	value	5	0.52	0.47	0.61	0.06	0.60

The geometric mean diameter, sphericity, and surface area were found to be in the range of 7.56 – 8.55 mm, 56.41 – 63.93 %, and 1.80 – 2.30 cm^2, respectively. The reported values for geometric mean diameter and surface area for dent corn seeds (Ismail *et al.,* 2011) were smaller while that for sphericity was higher. In contrast, geometric mean diameter (8.46mm) obtained by Seyed *et al.* (2006) for red cultivar of watermelon seeds was higher while that for sphericity (44.60 %) was smaller than that of STSs.

The low sphericity of STSs (59.00 %) indicates that they are likely to slide on their flat surfaces rather than roll. Judging by the criteria given by Bal & Mishra (1988) and Garnayak *et al.* (2008), which considered grain, fruit, and seed as spherical when the sphericity value is more than 80.0 and 70.0 %, respectively, STSs under this investigation can therefore be referred to as nearly elliptical and not spherical based on the sphericity values obtained were less than 70 – 80 %.

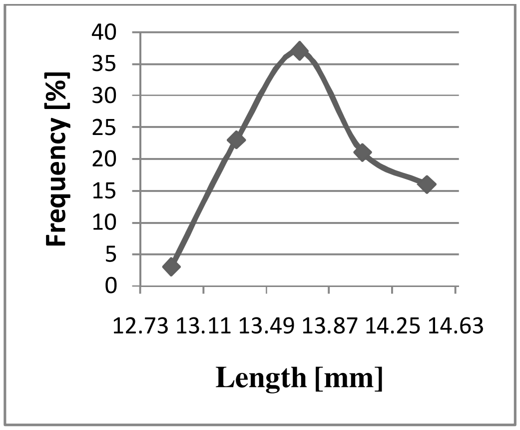

Figure 1a

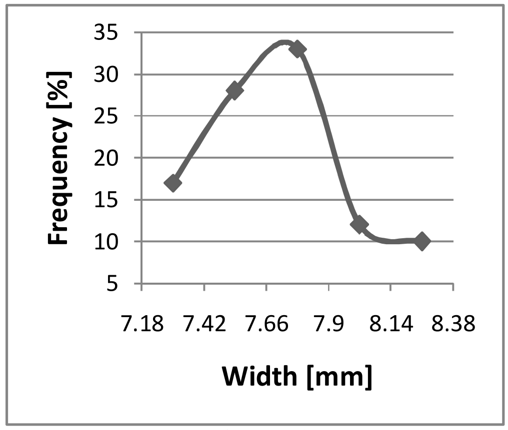

Figure 1b

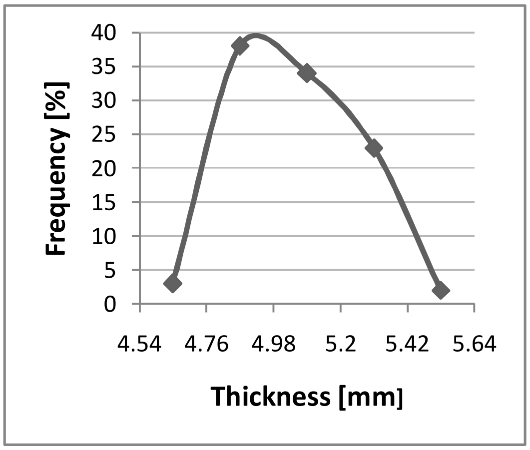

Figure 1c

Figures 1a, 1b, and 1c: Size distribution curve for STSs' (a) Length, (b) Width, and (c) Thickness

Unit Volume, Bulk Volume, Weight, Density and Porosity

The Unit volume, Bulk volume, True density, and Bulk density were in the ranges of 24.00 – 30.00 cm^3, 42.00-48.00 cm^3, 0.67-0.80 g cm^{-3}, and 0.42 – 0.46 g cm^{-3}, respectively. The obtained values for true and bulk density (0.73 g cm^{-3} and 0.44 g cm^{-3}) for STSs were smaller than that of dent corn seeds for both Simon and Goldeclat cultivars (1.4 g cm^{-3} and 0.73 g cm^{-3}) and (1.45 g cm^{-3} and 0.77 g cm^{-3}) (Ismail *et al.,* 2011). However, true and bulk density (0.86 g cm^{-3} and 0.45 g cm^{-3}) obtained by Seyed *et al.* (2006) for red cultivar of watermelon seeds, (1.46 g cm^{-3} and 0.63 g cm^{-3}) found by Bamgboye & Adejumo[2009] for Roselle seeds were higher than the values obtained for STSs.One thousand seed mass ranged between 192.10 – 202.10 g, with a mean value of 197.61 g. The mean porosity (39.85 %) obtained for STSs is smaller compared to 47.60 % found for red cultivar of watermelon seeds (Seyed *et al.,* 2006), 57.3 % for Roselle seeds (Bamgboye & Adejumo2009) and 95.9 % for sandbox seeds (Idowu *et al.,* 2012). The value obtained for porosity is solely dependent on the true and bulk density. This can be furthered explained from obtained result that aeration through the seeds will be less efficient in STSs (39.85 %) compared to red cultivar of watermelon seeds (47.60 %), roselle seeds (57.3 %), and sandbox seeds (95.9 %).

Surface Area and Specific Surface Area

The surface area and specific surface area investigated were in the range of 1.80 – 2.30 cm^2 and 6.89 – 8.71 cm^2 cm^{-3}, respectively. The mean value of surface area (2.08 cm^2) obtained for STSs is smaller than that of dent corn seeds for both Simon and Goldeclat cultivars at 17.00 and 16.48 % wb (Ismail *et al.,* 2011), sandbox seeds at 9.3 % wb (Idowu *et al.,* 2012).

Static Angle of Repose and Coefficient of Static Friction

The static angle of repose was in the range of 30.96^0 – 36.19^0 at 16.56 % db. The average value obtained (33.24^0) for STSs is higher compared to 24.10^0 for Roselle seeds (Bamgboye & Adejumo2009), 19.2^0 for sandbox seeds (Idowu *et al.,* 2012). The values found by Seyed *et al.* (2006) for Sarakhsy, Kolaleh and Red cultivars of watermelon seeds were within the range obtained for STSs.

It was observed that the coefficient of static friction was highest against plywood (0.75 ± 0.05), followed by rubber (0.68 ± 0.06), aluminium (0.52 ± 0.06), while the least was observed on stainless steel (0.47 ± 0.06). Similar trend was found for Roselle seeds at 15.56 % db (plywood 0.43, mild steel 0.29, and glass 0.25) (Bamgboye & Adejumo2009). It was observed that the smoother the structural surface the lower the coefficient of friction static of agricultural products.

CONCLUSIONS

The following conclusions are drawn from the investigation:

1. The mean values of length, width, thickness and geometric mean diameter of snake tomato seed were 13.80, 7.72, 5.07 and 8.14 mm, respectively. The mean sphericity of 59.00 % was obtained.
2. The mean of unit and bulk volume, true and bulk density were found to be 27.20 cm^3, 45.20 cm^3, 0.73 g cm^{-3}, and 0.44 g cm^{-3}, respectively.
3. The mean values of surface area and specific surface area were 2.08 cm^2, and 7.69 cm^2 cm^{-3}, respectively.
4. The average value of static angle of repose was 33.24^0 while coefficient of static friction against steel sheet, ply wood, rubber, and aluminium were 0.47, 0.75, 0.68, and 0.52, respectively.

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