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Physical and Engineering Properties of Some Nigerian Sweet Potato Roots [*Ipomoea Batatas* (L.) Lam]

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Abstract

Several varieties of sweet potato are being cultivated by many countries of the world including Nigeria. Data on physical and engineering properties required for the design and fabrication of handling and processing equipment for these important horticultural produce are either few or non-available. In this study the proximate composition and several physical and engineering properties of four popular varieties of Nigerian sweet potato (size, shape, mass, weight, volume, surface area, density, sphericity, latent heat, specific heat, thermal conductivity, thermal diffusivity) were determined using standard procedures. The surface areas for orange fleshed sweet potato (OFSP), yellow fleshed sweet potato (YFSP), purple fleshed sweet potato (PFSP) and white fleshed sweet potato (WFSP) are 2.36±0.30, 2.92±0.29, 2.43±0.41 and 1.97±0.19 ($\times 10^4$ mm^2) respectively. The geometric mean diameter obtained are 82.02±5.43, 95.17±4.61, 84.33±8.27 and 77.03±4.02 mm for OFSP, YFSP, PFSP and WFSP respectively. The values for sphericity were OFSP, 54.15±3.00; YFSP, 55.82±4.55; PFSP, 59.31±4.15 and WFSP, 54.75±1.58 %. The latent heat ranged between 198.08±0.71 and 272.10±0.33 KJKg-1. Orange fleshed sweet potato had the highest thermal conductivity of 0.55±0.001 Wm^{-1}K^{-1}.while purple fleshed and white fleshed sweet potato had the lowest value of 0.44±0.001 Wm^{-1}K^{-1}. The specific heat capacity values were OFSP, 3.69±0.03; YFSP, 3.18±0.01; PFSP, 3.11±0.01 and WFSP, 3.11±0.02 KJ Kg^{-1}K^{-1}. Properties such as major diameters, intermediate diameters, sphericities, aspect ratio, unit volume, unit mass and unit weight were found not to be statistically different at $P \leq 0.05$ ±SD.

Keywords: Physical; Thermal; Engineering; Properties; Sweet potato; Roots

Introduction

Sweet potato is the seventh most important food crop and next to cassava among the root and tuber crops grown in the world [1]. Bulkiness, storage problems, transportation and relatively low cash value per unit weight have resulted in very low level of importance in international trade. According to Naskar, et al. [2] sweet potato is expected to lead in the fight against food shortages and the resultant malnutrition that may likely occur due to population explosion and the attendant over usage of land. It can produce high amount of calories in a unit area and in a unit time. Sweet potato efficiency of production of consumable energy is outstanding in the developing countries [3].

Fresh roots and tubers must be converted to non-perishable commodities through processing operations in order to reduce post-harvest losses [4]. According to Balami, et al. [5] the ever increasing importance of agricultural products along with the complexity of modern technology being utilized for their production, processing and storage require a good knowledge of their engineering properties. It is necessary to understand the physical laws guiding the response of agricultural produce so that machines, processes and handling operations can be designed for maximum efficiency and the highest quality of the final products [6]. Over the years most agricultural produce have been underexploited in their region of production especially in developing countries. The present numerous use of sweet potato makes it a necessity to determine the engineering properties of this highly valuable agricultural produce so that more elaborate study can be undertaken in order to determine and locate more areas of sweet potato importance. According to Tabatabaeefar and Rajabipour [7] physical characteristics of agricultural products are the most important parameters to determine the proper standard of design of grading, conveying, processing and packaging systems.

The knowledge of engineering properties of food materials such as density, specific heat capacity, thermal conductivity, and thermal diffusivity is necessary not only because they are important on their own right but also because they are the commonest indicators of other properties and qualities [8].

The shortage or non-availability of machines and equipment for processing operations and preservation for sweet potato, which may be as a result that data on the engineering properties of sweet potato needed for the design of the machines are either insufficient or non-available.

The objective of this study was to determine the relevant physical and engineering properties of four popular sweet potato varieties (size, shape, mass, weight, volume, surface area, density, sphericity, latent heat, specific heat, thermal conductivity, thermal diffusivity) that are considered important in designing of agricultural machinery and equipment for handling, packing, conveying, separation, dehydration, size reduction, sieving, packaging etc.

Materials and Methods

Materials

Four months old freshly harvested improved varieties of sweet potatoes namely Umuspo 3 (orange flesh), Ex Kwara (light purple flesh), TIS80/0140 (light yellow flesh), and TIS1499 (white flesh) sweet potatoes were obtained from an experimental farm of the Nigerian Root Crops Research Institute (NRCRI), Umudike, Nigeria.

Methods

Proximate Composition: The proximate analyses of the fresh sweet potatoes were conducted in accordance with the methods described in AOAC [9].

Determination of engineering properties

Density: The solid density and relative density were determined using the simple floatation principle. Equal mass (10g) of each sample was weighed using the Ohau analytical balance. The sample was dropped into 250 ml measuring cylinder containing 100 ml toluene (as floatation liquid) and the difference in volume noted. The difference is the volume occupied by the 10g sample. Density therefore, is the mass of sample divided by the volume occupied by the sample. All experiments were done in ten replicates.

Root Mass

The root masses of each of the sweet potato varieties were determined by weighing one hundred roots selected at random using Ohau analytical balance.

Root size

Twenty (20) roots each were selected at random from each batch of the four sweet potato varieties. The root size, in terms of the major diameter (L), intermediate diameter (W) and minor diameter (T) of the roots were measured using a vernier caliper (Kennedy Tools) reading to 0.01 mm. Determination was replicated twenty times. The average diameter was estimated by using the arithmetic mean and geometric means of the three axial dimensions. The arithmetic mean diameter, $D_{a,}$ equivalent diameter, D_p and geometric mean diameter, D_g in mm of roots were estimated using the methods of Galedar, et al. 2008; Mohsenin, 1986; and Bahnasawy, 2007 [10-12] respectively as

$$D_a = \frac{(L+W+T)}{3} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

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

$$D_p = [L\frac{(W+T)2}{4}]^{1/3} \quad \ldots\ldots..(3)$$

Where D_a is the arithmetic mean diameter (mm), D_g is the geometric mean diameter (mm), D_p is the equivalent diameter (mm), L is the length (mm), W is the width (mm), and T is the thickness (mm).

Sphericity

The sphericity (S_p) defined as the ratio of the surface area of the sphere having the same volume as that of the root to the surface area of the root, was estimated by the method of Mohsenin [11] as

$$S_p = \frac{(LWT)1/3}{L} \text{ .... (4)}$$

Surface area

The surface area was estimated using the formula

$$S = \pi D_g^{\ 2} \text{ ....(5)}$$

Aspect ratio

The aspect ratio (R) was estimated using the method of Omobouwajo, et al [13]. as

$$R_a = \left(\frac{W}{L}\right) 100 \text{ ....(6)}$$

Unit volume

The unit volume of 100 individual roots was estimated from the values of length (L), width (W) and thickness (T) using the method of Mohsenin [11] as

$$V = \frac{\pi}{6}(LWT) \text{ ....(7)}$$

Thermal conductivity

The thermal conductivity (K) of food materials is related to the composition of the material and was estimated using the method described by Sweat [14] as

$$K = 0.25m_c + 0.155m_p + 0.16m_f + 0.135m_a + 0.58m_m \text{ ....(8)}$$

Where, m_c = mass of carbohydrate, m_p = mass of protein, m_f = mass of fat, m_a = mass of ash and m_m = mass of moisture present in the food material.

Specific heat capacity

The specific heat capacity of the roots were estimated using the method of Miles, et al. [15] as

$$C_p = m_w c_w + m_s c_s \text{ (KJ Kg}^{-1}\text{K}^{-1}\text{) ....(9)}$$

Where, c_p = specific heat capacity, m_w = mass fraction of water, c_w = specific heat capacity of water (4.18 KJ $Kg^{-1}k^{-1}$), m_s = mass fraction of solids, and c_s = specific heat capacity of solids (1.46 KJ $Kg^{-1}K^{-1}$).

Latent heat of fussion

The method of Lamb [16] was used to estimate the latent heat of fussion as

$$L = 335\, m_w \text{ (KJ Kg}^{-1}\text{) ....(10)}$$

Where, m_w = mass fraction of water.

Thermal diffusivity

The thermal diffusivity was estimated as described by Lewis [17] as

$$\alpha = K/\rho C_p$$

where α = thermal diffusivity, K = thermal conductivity, ρ = density, c_p = specific heat capacity.

Statistical analysis

The results obtained from all determinations conducted on the four sweet potato varieties were subjected to multiple comparisons test and ANOVA using SPSS version 17.0 software.

Results and Discussion

Proximate Composition

The proximate analysis of fresh sweet potato varieties is presented in Table 1. The moisture content ranged from 64.47±0.81% to 73.47±0.15%. The moisture content of orange flesh sweet potato 73.47±0.15% is significantly higher than all other samples, followed by purple flesh sweet potato. Significant difference does not exist between the moisture content of yellow flesh and white flesh sweet potatoes. Nicanuru, et al. reported a moisture content range of 64.50±0.32%-70.40±0.17% for OFSP [18]. Ingabire and Hilda (2011) reported a range of 62.78±0.70 and 64.03±0.84 for yellow variety and 62.58±0.42 and 64.34±0.42 for white variety [19]. Hock-Hin and Van-den reported a range between 60.00 and 73.10% for about ten different varieties [20]. Onuh, et al reported 68.40±0.1 for red variety and 70.80±0.50 for white variety [21]. Omodamiro, et al. evaluated about fifteen (15) genotypes and reported a moisture content of the range 59.10% and 71.25% [22].

Parameter	OFSP	YFSP	PFSP	WFSP
Moisture Content	73.47±0.15^{a}	64.47±0.81^{c}	68.85±0.11^{b}	66.20±0.10^{c}
Protein	1.83±0.07^{a}	2.00±0.07^{a}	1.89±0.07^{a}	1.93±0.08^{a}
Fat	0.49±0.03^{a}	0.44±0.02^{a}	0.46±0.07^{a}	0.38±0.03^{a}
Ash	1.00±0.08^{a}	0.95±0.01^{a}	0.84±0.05^{b}	0.78±0.03^{b}
Fiber	3.04±0.06^{a}	1.53±0.05^{b}	2.22±0.04^{c}	1.81±0.08^{d}
Carbohydrate	20.21±0.14^{a}	30.61±0.75^{b}	25.74±0.13^{c}	28.90±0.10^{b}

Values with the same superscript along rows do not differ significantly at $P \leq 0.05$ ±SD

Table 1: Proximate analysis of fresh sweet potato (g/100g).

The protein contents of the four varieties evaluated ranged between 1.83±0.07% and 2.00±0.07%. Orange flesh had the lowest and yellow flesh had the highest values. But the values are not significantly different. Namhong, et al. (2016) documented a range of 0.88% - 1.83% for white, yellow, light purple, and dark purple [23]; the value 1.83% is similar to the value 1.89 reported in this experiment for the purple fleshed. Nicanuru, et al. [18] reported a range of 1.90±0.08% - 2.70±0.41% for OFSP. Ingabire and Hilda [19] reported a range of 0.71±0.03 and 0.91±0.05% for yellow variety and a range of 0.80±0.02 and 0.81±0.09% for white variety. Ali *et al* (2012) reported a range of 2.10% and 2.5% [24]. Nepa (2006), Unifesp (2008), Soares, et al. (2002), and Ruiz (1984) as cited by Antonio, et al. (2011) reported 1.00%, 2.00%, 2.00 – 2.90% and 4.13% respectively. Onuh, et al. (2004) reported values of 1.2± 0.00% for red variety and 2.3±0.0% for white variety. The variations observed may be due to various levels of fertilization or agronomical practices.

The fat contents ranged from 0.38±0.03% to 0.49±0.03%. Orange flesh had the highest while white flesh had the lowest values. All the values obtained are not significantly different from one another. But the value 0.21% reported by Namhong, et al. (2016) for WFSP was lower than that reported in this study while 1.08% reported for PFSP was higher than the figure reported in this work [23]. The values of 0.40±0.00% documented for the red and white varieties by Onuh, et al. (2004) are in agreement with the values obtained in this experiment [21]. While the values, 1.10±0.06% - 1.70±0.08%, obtained by Nicanuru, et al. (2015) are higher than the values recorded in this study [18].

The ash content was observed to be between 0.78±0.03% and 1.00±0.08%. The values for orange flesh and yellow flesh do not differ significantly from one another but are significantly higher than those of purple and white flesh. Ingabire and Hilda (2011) reported a range between 0.40±0.02% and 0.42±0.07% for white variety and a range between 0.43±0.09 and 0.44±0.07% for yellow flesh [19]. Antonio, et al. (2011) recorded a range from 0.60% to 2.68%, while Ali, et al. (2011) documented a range of 2.1 and 2.8% [25]. Nicanuru, et al. (2015) noted a higher range of 2.80±0.01–4.20±0.07% for OFSP [18].

The fiber content ranged from 1.53±0.05% to 3.04±0.06%. Orange flesh had the highest value followed by purple flesh, white flesh and yellow flesh. The value for orange flesh is significantly higher than the rest samples. Ingabire and Hilda (2011) reported values between 0.11±0.00 and 0.12±0.01% for white variety and between 0.12±0.01 and 0.14±0.00% for yellow variety [19]. Antonio, et al. (2011) recorded a range between 1.30 and 3.8% while Nicanuru, et al. (2015) noted a higher range of 3.00±0.05 – 3.6±0.08% [18,25]. The values 0.85% and 1.50% reported by Namhong, et al. (2016) for white fleshed and purple fleshed respectively were found to be far lower than the values 1.81% and 2.22% reported in this study [23].

The carbohydrate values ranged from 20.21±0.14% to 30.61±0.75%. Yellow flesh had the highest value, followed by white flesh, purple flesh and orange flesh. Onuh, et al. (2004) reported a carbohydrate content of 27.90±0.00% for red and 24.50±0.2% for white varieties [21]. Namhong, et al. (2016) reported 18.44% and 29.23% for white fleshed and purple fleshed respectively [23], but Nicanuru, et al. (2015) recorded a lower range of 18.30±0.07 – 26.10±0.04% [18].

Physical Properties

The results of determination of the physical properties are presented in Table 2. The major diameters ranged between 151.53±6.23 and 171.59±11.58 mm with PFSP having the lowest value and YFSP having the highest. There were no significant differences among the values at $P \leq 0.05$ level.

The intermediate diameters ranged from 64.01±3.44 to 75.32±4.77 mm. significant difference did not exist among the varieties in terms of intermediate diameters. The values for the minor diameters was lowest in WFSP (57.48±1.89 mm) and highest in YFSP (69.09±4.85 mm). Arithmetic mean diameters ranged between 91.10±3.67 mm and 105.33±4.98 mm. The value for YFSP was significantly higher than all other varieties. But there was no significant difference among OFSP, PFSP and WFSP. The geometric mean diameter values were between 77.03±4.02 mm and 95.17±4.61 mm. The value for YFSP was significantly higher than the values for all other varieties. But the values for OFSP, PFSP and WFSP were not significantly different at $P \leq 0.05$ level.

When axial dimensions of produce are known they can be effectively graded [5]. The knowledge of the various dimensions are important in order to reduce breakages during grading, peeling and cleaning unit operations.

The value for sphericity ranged between 54.15±3.00 % and 59.31±4.15 %. The values obtained for OFSP, YFSP and WFSP are lower than while PFSP is within the range 56 % to 62 % reported for cocoyam by Balami *et al* [5]. There was no significant difference among all the varieties. The sphericity values of most agricultural produce was reported to range between 0.32 and 1.00 % and that the more regular an agricultural produce is, the lower is the sphericity [6]. This implies that OFSP, YFSP and WFSP are more regular than PFSP and also these are more regular than the cocoyam.

The surface area values were between 1.97±0.19 × 10^4 mm^2 and 2.92±0.29 × 10^4 mm^2. The value for WFSP was significantly lower than the values for all other varieties. The values for OFSP, YFSP and PFSP did not differ significantly at $P \leq 0.05$ level. The unit volume values ranged from 314.32±35.69 cm^3 to 439.74±76.54 cm^3. All the values obtained did not differ significantly at $P \leq 0.05$ level. Also the values for unit weight and the unit mass for all the varieties did not differ significantly at $P \leq 0.05$ level.

The true density for all varieties ranged between 979.36±9.93 Kgm^{-3} and 1157.09±17.06 Kgm^{-3}. The value foe OFSP was significantly lower than the values for all other varieties. The values for PFSP and WFSP were not significantly different from each other at $P \leq 0.05$ level. The values reported in this experiment are lower than the range 1149.43±0.764 to 1234.57±0.577 Kg m^{-3} reported by Oke, et al. (2007) for an unspecified sweet potato variety [8]. The difference may be due to varietal differences, maturity at harvest, and if the produce were kept in storage before using for experiment, in which case they would have been subjected to both respiration and transpiration losses.

Parameter	Unit	OFSP	YFSP	PFSP	WFSP
MAD	Mm	166.77±9.52^{a}	171.59±11.58^{a}	151.53±6.23^{a}	152.64±7.54^{a}
ITD	Mm	64.58±4.25^{a}	75.32±4.77^{a}	65.78±6.23^{a}	64.01±3.44^{a}
MID	Mm	61.91±3.93^{ab}	69.09±4.85^{b}	67.40±6.70^{ab}	57.48±1.89^{a}
AMD	Mm	97.82±4.32^{a}	105.33±4.98^{b}	95.91±6.19^{a}	91.10±3.67^{a}
GMD	Mm	82.02±5.43^{ab}	95.17±4.61^{b}	84.33±8.27^{ab}	77.03±4.02^{a}
EQD	Mm	86.11±4.20^{ab}	95.37±4.61^{b}	86.69±5.95^{ab}	82.68±3.13^{a}
Sphericity	%	54.15±3.00^{a}	55.82±4.55^{a}	59.31±4.15^{a}	54.75±1.58^{a}
Surface area	×10^{4}mm^{2}	2.36±0.30^{b}	2.92±0.29^{b}	2.43±0.41^{ab}	1.97±0.19^{a}
Aspect ratio	%	41.22±3.33^{a}	46.95±5.35^{a}	47.22±5.09^{a}	42.92±2.17^{a}
Unit volume	cm^{3}	383.48±65.58^{a}	439.74±76.54^{a}	403.40±88.89^{a}	314.32±35.69^{a}
Unit mass	G	531.40±118.54^{a}	500.29±94.35^{a}	473.52±109.61^{a}	449.42±58.18^{a}
Unit weight	N	5.21±1.16^{a}	4.91±0.93^{a}	4.64±1.07^{a}	4.40±0.57^{a}
True density	Kgm^{-3}	979.36±9.93^{c}	1098.52±17.42^{b}	1157.09±17.06^{a}	1139.00±28.3^{a}
RD	Kgm^{-3}	0.98±0.01^{c}	1.10±0.02^{b}	1.16±0.02^{a}	1.14±0.09^{ab}

Values with the same superscript along rows do not differ significantly at $P \leq 0.05$ ±SD
MAD=major diameter, ITD=intermediate diameter, MID=minor diameter, AMD =arithmetic mean diameter, GMD=geometric mean diameter, EQD=equivalent diameter, RD=relative density.
Table 2: Physical properties of fresh sweet potato.

Thermal properties

The result of the thermal properties of the sweet potato varieties are presented in Table 3. The values for thermal conductivity ranged between 0.44±0.001 Wm^{-1}K^{-1} and 0.55±0.001 Wm^{-1}K^{-1}. The value for OFSP was significantly higher than the values for all other varieties followed by that of YFSP. The values for PFSP and WFSP were not significantly different at P≤0.05 level. The values reported in this experiment are higher than the range 0.107±0.048 to 0.217±0.023 $Wm^{-1}K^{-1}$ for an unspecified sweet potato variety by Oke, et al. (2007) but within the range 0.4770 to 0.6102 $Wm^{-1}K^{-1}$ reported for cassava by Oriola (2014). This implies that all the varieties studied are better heat conductors and heat energy transfer during drying, cooling and similar operations would be faster than those of Oke, et al. (2007) [8].

Parameter	Unit	OFSP	YFSP	PFSP	WFSP
Thermal conductivity	$Wm^{-1}K^{-1}$	0.55 ± 0.001^c	0.45 ± 0.002^b	0.44 ± 0.001^a	0.44 ± 0.001^a
Thermal diffusivity	$\times10^{-7}m^2s^{-1}$	1.51 ± 0.01^c	1.29 ± 0.02^b	1.22 ± 0.02^a	1.24 ± 0.03^a
Specific heat capacity	$KJ\ Kg^{-1}K^{-1}$	3.69 ± 0.03^c	3.18 ± 0.01^b	3.11 ± 0.01^a	3.11 ± 0.02^a
Latent heat of fussion	$KJ\ Kg^{-1}$	272.10 ± 0.33^c	206.91 ± 1.70^b	198.08 ± 0.71^a	198.41 ± 0.67^a

Values with the same superscript along rows do not differ significantly at P ≤ 0.05 ±SD

Table 3: Thermal properties of fresh sweet potato.

Thermal diffusivity values ranged from 1.22±0.02 × $10^{-7}m^2s^{-1}$ to 1.51±0.01 × $10^{-7}m^2s^{-1}$ with OFSP having the highest and PFSP the lowest values. The thermal diffusivity of OFSP was significantly higher than the values for all other varieties. There was no significant difference between the values obtained for PFSP and WFSP. The values reported in this study are higher than the range 3.208 × 10^{-8} to 9.203 × 10^{-8} m^2s^{-1} and 2.918 × 10^{-8} 8.823 × 10^{-8} m^2s^{-1} for slab and cylindrical geometries respectively as reported by Oke, et al. (2007) [8]. Similarly the values obtained in this experiment are higher than 6.688 × 10^{-8} – 8.823 × 10^{-8} m^2s^{-1} reported for an unspecified sweet potato variety by Farinu and Baik (2007) and the values 2.365 × 10^{-8} to 11.86 ×10^{-8} m^2s^{-1} reported for yam by Oke, et al. (2008) [26]. Also the values for thermal diffusivity obtained in this study are within the range 1.432 × 10^{-7} to 2.426 × 10^{-7} m^2s^{-1} for cassava by Oriola (2014) [27]. The low thermal diffusivity is an indication that these varieties of sweet potato would conserve and take more time to loss heat whereas it would conduct heat at a faster rate due ti its high thermal conductivity values.

The specific heat capacity ranged between 3.11±0.01 and 3.64±0.03 KJ $Kg^{-1}K^{-1}$. The specific heat for OFSP was significantly higher than the values for all other varieties, followed by the value for YFSP, the WFSP and lastly by PFSP. The values for WFSP and PFSP were not significantly different from each other. The values for specific heat obtained in this study were higher than 1.254±0.870 to 2.768±0.430 KJ $kg^{-1}\,{}^0C^{-1}$ and 2.3626 to 3.1495 KJ $Kg^{-1}K^{-1}$ reported by Oke *et al* (2007) for sweet potato and Oriola (2014) for cassava respectively [8,27]. However, the specific heat reported in this experiment were found to be lower than 3.33±0.12, 3.53±0.10 and 3.70±0.007 KJ $Kg^{-1}K^{-1}$ recorded for cocoyam, yam and cassava respectively by Nwanekezi and Ukagu (1999) [28]. The higher the specific heat value the more heat energy is required to raise or lower the temperature of produce. Specific heat capacity values are required in estimating the sensible heat or heat of respiration in cold storage of fresh horticultural produce.

The latent heat fussion values ranged between 198.08±0.71 KJ Kg^{-1} and 272.10±0.33 KJ Kg^{-1} with OFSP being significantly higher than the values for all other varieties. The values for PFSP and WFSP are not significantly different at P≤0.05 level. This implies that more heat energy would be needed to heat or freeze a specified weight of OFSP than other varieties. The latent heats obtained for YFSP, PFSP and WFSP are however lower than 221.40±0.10, 248.90±0.20 and 221.40±0.20 reported for cocoyam, yam and cassava respectively by Nwanekezi and Ukagu (1999) [28]. Latent heat of food materials are required for calculation of the refrigeration load if the materials are destined for frozen storage.

Conclusion

Physical and thermal properties of orange fleshed, yellow fleshed, purple fleshed and white fleshed sweet potato roots which are required in designing of handling and processing equipment were determined. Properties such as minor diameters, arithmetic mean diameters, geometric mean diameters, equivalent diameters, surface areas, densities, thermal conductivities, thermal diffusivities, specific heats and latent heats were found to be significantly different. But properties such as major diameters, intermediate diameters, sphericities, aspect ratios, unit volume, unit mass and unit weight were found not to be significantly different.

The values for specific heats are high meaning that a lot of energy will be needed to heat or cool these produce. The roots had low thermal conductivities indicating that these produce are poor conductors of heat and since the thermal diffusivities are also low, they are expected to conserve and loss heat at slower rates. This means that heat energy diffusion or transfer as in drying, evaporation, cooling, freezing and thawing will be occur at slow rate.

Conflict of Interest

The authors confirms that they do not have any conflict of interest.

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