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Moisture Dependent Physical Properties of Litchi Seeds (*Litchi chinensis*)

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Abstract

This study was conducted to investigate the selected physical properties of litchi seeds as a function of their moisture content. Three lots of litchi seeds having variation in their moisture content were taken for experimentation. Parameters considered in the study includes length, width, thickness, diameter, colour, sphericity, geometric mean diameter, surface area, porosity, volume, bulk density, true density, angle of repose and coefficient of static friction were recorded for all the three lots during experimentation. It can be observed that the physical properties were governed by the inherited moisture content of the seeds.

Keywords: Physical Properties; Moisture Content; Litchi Seeds

Introduction

Lychee (*Litchi chinensis* Sonn) belongs to Sapindacae family and is considered to be an important sub-tropical fruit crop of India. Origin of this fruit is believed to be China and altogether India and China account for 91 percentage of the world lychee production [1]. It is botanically designated and widely known as litchi. The various cultivars of litchi vary widely intexture, size, shape, color due to cultivar differences but alsoin biochemical composition and their levels [2]. The fruit consist of a single seed coveted by an agreeable sweet-acid tasting, crisp, white, juicy, translucent aril or pulp, which is high in vitamin C. Litchi fruits has no competition from other fruits as it comes in the market in May-June and faces no marketing problem.The area under Litchi production is 85Mha with a production of 585.3MT and the productivity is reported to be 7MT/ha [3]. Bihar is the leading litchi growing states in the country and Assam, Orissa, Punjab, Tripura, Uttarakhand, West Bengal are the other states [4].

In order to design equipment used in plantation, harvesting, transportation, post-harvest and storage of any particular agricultural commodity, understanding of relevant physical properties with respect to cultivar and moisture content is very important. The size, shape and mechanical behaviour are important in designing of harvesting, separating, sizing and grading machines.

There are plentiful reported studies which includes determination of physical properties of commodities as a function of moisture content for fenugreek (*Trigonella foenum-graceum*) seeds [5], jatropha (*Jatropha curcas* L.) seeds [6], guar seeds [7], melon (*Cucumis melo* L.) seeds and kernels [8] and date palm fruits [9]. However, there was no published literature which deals with the determination of physical properties of Litchi seeds as a function of its moisture content. Therefore, this particular research investigation was envisaged to investigate the effect of moisture content of the moisture dependent properties such as linear dimesnions, sphericity, thousand seed weight, bulk density, true density, porosity, specific gravity and coefficient of friction between 40-48% (w.b.)moisture content.

Materials and Methods

Procurement of raw material

Fresh fruits of Litchi were brought from the local market of Abohar in the state of Punjab, and were washed by water, drained by tissue paper to remove droplets of water present on the surface. The purpose of washing was not only to remove field soil and surface microorganisms but also to remove fungicides, insecticides and other pesticides from the litchi.

Sample preparation

To acquire a better comparison of the physical properties with the moisture content, the fresh seeds were kept for drying for 15 hours at room temperature (38±3˚C) and some seeds were kept for soaking in water for 24 hours simultaneously. Performing this practice, 3 different seeds sample with variation in their moisture content and physical attributes were obtained (Figure 1). These samples were further used for the estimation of physical properties.

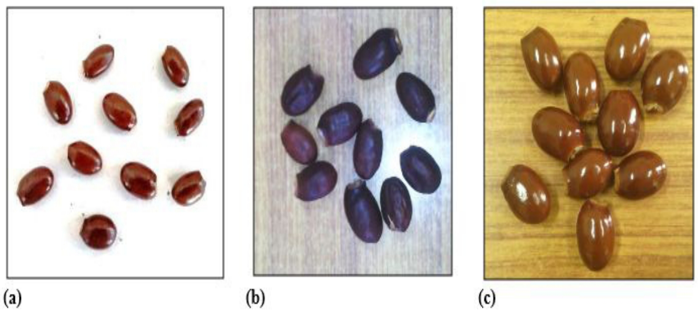

Figure 1: Pictorial view of the seeds taken for experimentation (a) Freshseeds (b) Dried seeds (c) Soaked seeds.

Moisture content

Moisture content of the seeds was determined by using the standard method given by Suthar and Das (1996) [10] as given below:

Moisture content (%w.b.): $\frac{Initialweight - Finalweight}{Intialweight}$

Axial dimensions

Litchi peel was removed manually and the dimensions of randomly selected 10 seeds were taken using digital vernier caliper (Mitutoyo, Japan) with an accuracy of 0.01mm. Length, width and thickness of seeds were measured which helped in estimation of arithmetic and geometric mean diameter of the three lots. Arithmetic mean diameter (D_a) and geometric mean diameter (D_g) of the seed were calculated by using the following relationships (Mohsenin, 1970) [11]:

$$D_a = \frac{L + W + TL + W + T}{3 \qquad\qquad 3}$$

$$D_g = (L\times W\times T)^{1/3}$$

Sphericity

Sphericity (Φ) of litchi seed was calculated by using the following relationship (Mohsenin, 1970) [11]:

$$\Phi = \frac{(LWT)\ 1/3(LWT)\ 1/3}{L \qquad\qquad L}$$

Where, L is the length, W the width and T is the thickness, all in cm.

Thousand seed weight

The 1000 seed weight was determined by means of a digital electronic balance (Shimadzu Corporation, Japan, AY120) having an accuracy of 0.001 g. To evaluate the 1000 seed mass, 25 randomly selected seeds from each bulk sample were averaged.

Surface area

Surface area (S) of litchi seed was found by analogy with a sphere of the same geometric mean diameter, using the following relationship [5].

$$S = \pi D_p^2$$

Bulk density

It was measured using a wooden box with inside dimensions of 100× 100×100 mm. Seeds were poured into that box of known volume and removing excess seeds by rolling a measuring scale on the rim of the box without compacting the seeds [12]. Weight of the poured box was taken and the procedure was repeated five times and average bulk density (ρ_b) of the seeds was calculated by dividing the weight of seeds with the volume of box.

True density

True density defined as the ratio between the mass of litchi seeds and the true volume of the seeds, was determined using the toluene (C_7H_8) displacement method. Toluene was used in place of water because it is absorbed by seeds to a lesser extent. The volume of toluene displaced was found by immersing a weighted quantity of litchi seed in the toluene.

True density (ρ_t) = Weight of seeds/Toluene displaced

Porosity

Porosity(ε) of bulk seed was calculated using the relationship given by Mohsenin(1970).

$$\varepsilon = 100(1-\rho_b/\ \rho_t)$$

Where, ε is the porosity (%), ρ_b the bulk density (kg/m³), and ρ_t is the true density (kg/m³).

Specific gravity

Specific gravity of the seed samples was determined using following formula:

(SG of toluene ×Weight of seeds)/ (Weight of toluene displaced by the seeds)

SG of toluene = Weight of toluene/ weight of water

Coefficient of friction

Static coefficients of friction of litchi seeds against four different surfaces namely plywood, stainless steel, galvanized iron sheet and mild steel were determined using a single seed. With single seed resting on the surface, the surface was raised gradually until the seed just started to slide down. The coefficient of friction was calculated from the following relationship:

$$\mu = \tan \alpha$$

Where,'μ' is the coefficient of friction and 'α' is the angle of tilt in degrees.

Results and Discussion

Moisture content (M_c)

Moisture content of the Litchi seeds sampleswas found to vary from 40 to 48(% w.b.).

Axial dimensions

Average values of the three principal dimensions of litchi stones, namely, length, width and thickness determined in this study at different moisture contents are presented in Table 1. Each principal dimension appeared to be linearly dependent on the moisture content as shown in Figure 2. Higher correlation was observed between the three principal dimensions and moisture content indicating that upon moisture absorption, the litchi seeds expand in length, width and thickness within the moisture range of 40 to 48% w.b. The average length, width and thickness of the 10 seeds varied from 2.24-2.45 cm, 1.44-1.64 cm, 1.19-1.39cm, respectively with the increase in moisture content. Arithmetic and geometric mean diameter ranged from 2.18-2.24cm and 1.56- 1.78cm as the moisture content increased from 40 to 48 % w.b., respectively.

Samples	Mc (% w.b.)	L	W	T	D_a	D_g	Sphericity	m1000 (g)	S (cm^2)
Dried	40	2.24	1.44	1.19	2.18	1.56	0.70	2646.6	7.68
Fresh	44	2.38	1.55	1.29	2.19	1.68	0.71	3019.7	8.86
Soaked	48	2.45	1.64	1.40	2.24	1.78	0.72	3081.5	9.89

Table 1: Axial dimensions of litchi seed samples.

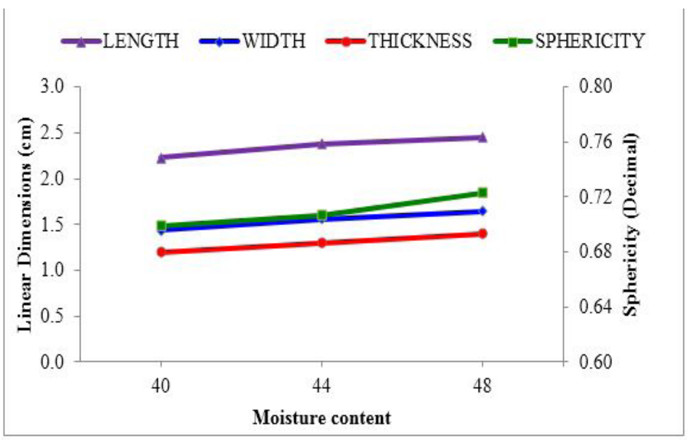

Figure 2: Variation of axial dimensions as a function of moisture content.

Sphericity

Sphericity of the litchi stones increased from 0.69-0.72 % as the moisture content increased from 40-48% w.b. The relationship between sphericity (Φ) and moisture content appears linear and can be represented by the following equation:

$$\Phi = 0.012(M_c) + 0.685 \quad R^2 = 0.96$$

Thousand seed weight

Thousand seed mass of litchi increased linearly from 2646.6 - 3081.5 g as the moisture content increased from 40-48 % w.b. Relationship between 1000 grain mass (m_{1000}) and the moisture content (M_c) can be represented by the following equation:

$$m_{1000} = 217.45(M_c) + 2481 \qquad R^2 = 0.85$$

Surface area

Surface area of litchi seeds increases linearly from 7.76-9.89 cm^2, when the moisture content increased from 40-48 % w.b.The variation of moisture content (M_c) and surface area (S) can be expressed mathematically as follows:

$$S = 1.107 (M_c) + 6.60 \qquad R^2 = 0.99$$

The dependency of thousand seed weight and surface area with respect to moisture content of litchi seeds is shown in Figure 3.

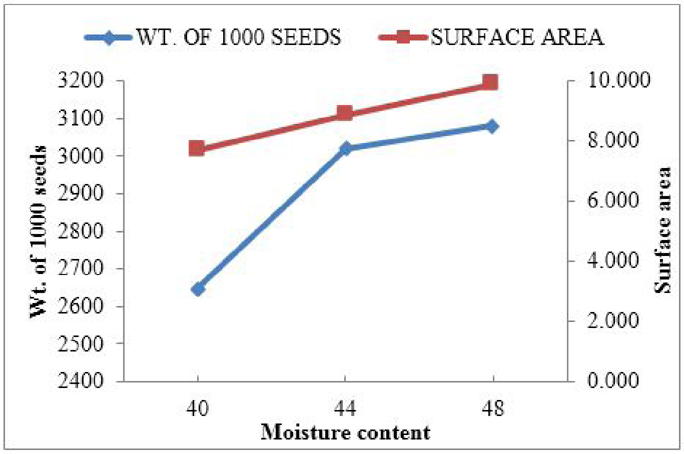

Figure 3: Variation of thousand seed weight and surface areaof litchi seeds as a function of moisture content.

Bulk density

Bulk density at different moisture levels varied from 577-680kg/m^3 and indicated an increase in bulk density with an increase in moisture content from 40-48 % w.b. The bulk density (ρ_b) of theseeds was found to have the following linear relationship with the moisture content (*M*):

$\rho_b = 12.875(M_c) + 78.1$ $R^2 = 0.77$

True density

True density of litchi seeds at different moisture contents varied from 1202.72-3150 kg/m^3. The effect of moisture content on true density of the stones showed an increase with increasing moisture content. Moisture dependence of the true density (ρ_t) was described by a linear equation as follows:

$\rho_t = 243.41(M_c) - 8856.5$ $R^2 = 0.75$

Porosity

The effect of porosity on bulk density and true density of the seeds showed a decrease from 52.02-21.58.Relationship between porosity (ε) value and the moisture content (*M*) of the seeds was obtained as:

$\varepsilon = -3.805(M_c) + 206.61$ $R^2 = 0.93$

The respective values of bulk density, true density, porosity and specific gravity of selected seed samples were indicated in Table 2. The graphical variation has been shown in Figure 4.

Bulk density (kg/m^3)	True density(kg/m^3)	Porosity (%)	Specific gravity
577.0	1202.72	52.02	1.04
676.8	1207.88	43.96	1.05
680.0	3150.00	21.58	1.21

Table 2: Bulk density, True density, Porosity and Specific gravity of seed samples.

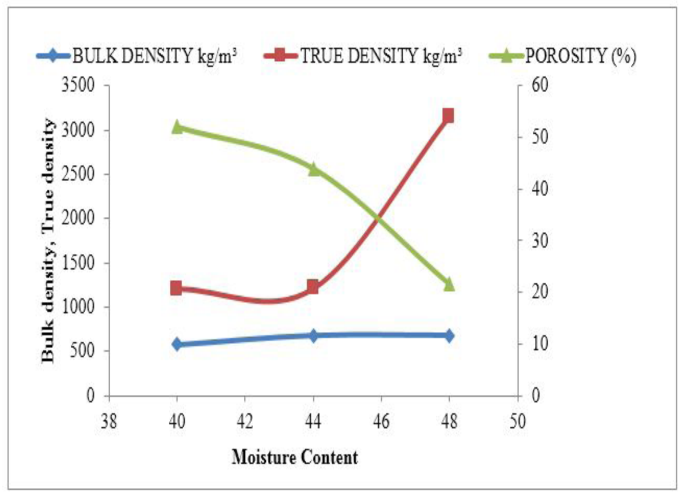

Figure 4: Variation of density values and porosity of litchi seeds as a function of moisture content Static coefficient of friction.

The static coefficient of friction values were found to be higher for all samples on plywood surface as compared to mild steel, stainless steel and galvanized iron (Table 3). This might be because as plywood provides maximum resistance to particle flow due to its roughness of surface as compared to other surfaces used.

Plywood			Mild steel			Stainless steel			Galvanized iron		
Dried	Fresh	Soaked	Dried	Fresh	Soaked	Dried	Fresh	Soaked	Dried	Fresh	Soaked
0.53	0.36	0.23	0.45	0.32	0.19	0.32	0.23	0.16	0.38	0.29	0.18

Table 3: Static coefficient of friction of seed samples on different surfaces.

Conclusion

This investigation includes determination of moisture dependent physical properties of Litchistones with respect to moisture content ranging from 40 to 48 % w.b. Physical properties of the stones were found dependent on moisture content. Axial dimensions, length, width and thickness showed a positive linear relationship with moisture content range from 2.24 to 2.45 cm, 1.44 to 1.64 cm and from 1.19 to 1.40 cm, respectively. Thousand grain weight and surface area increased from 2646.6 to 3081.5 g and from 7.68to 9.89 cm^2. On the other hand, the arithmetic and geometric mean diameter increased in a range between 2.18 to 2.24cm and 1.56 to 1.78 cm, respectively. Sphericity varied between 0.69 to 0.72 %.True and bulk densities decreased from 3150 to 1202.72 kg $m^{-3}$and from 680 to 577 kg m^{-3}, respectively while the porosity varies from 52.02 to 21.58 %. It could be observed the effect of the material in the coefficient of friction; it decreased for dried, fresh and soaked samples for all the four materials under study, i.e., plywood (0.531-0.23, galvanized iron (0.383-0.176), stainless steel (0.324-0.158) and mild steel (0.445-0.194).In brief, this part of study deals with physical and engineering properties of Litchi stones, enlarging knowledge about the changing behaviour of several properties with moisture content and providing useful data. Such information may find its applicability in design and development of related equipment pertaining to the particular crop.

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