Effects of Moisture Content on Some Physical Properties of *Lablab purpureus* (L.) Sweet Seeds

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ABSTRACT

The effects of moisture content on the physical properties of two varieties of *Lablab purpureus* (L.) sweet seeds, 'Rongai', and 'Highworth' were investigated. The physical properties investigated include length (L), width (W), thickness (T), arithmetic mean diameter, geometric mean diameter, equivalent diameter, sphericity, seed volume and weight, roundness, bulk density, particle density and porosity at moisture range of 9.7 to 29 % wet basis (w.b.) for 'Rongai' and 10.2 to 22.6 % (w.b.) for 'Highworth'. These properties are useful in the design of planting, harvesting, processing, handling and storage equipments. Results showed that the axial dimensions, arithmetic mean diameter, geometric mean diameter and equivalent diameter, individual grain mass, and volume increased with increasing moisture content. There was a decrease in roundness, bulk density and porosity with increasing moisture content.

Keywords: Physical properties, *Lablab*, moisture content, seed, Rongai, Highworth.

1. INTRODUCTION

Sources of cheaper alternative vegetable protein for animal feed stuff in developing countries have been a subject of research in recent years. *Lablab* (*Lablab purpureus* (L.) sweet) seed was explored as possible alternative for livestock feed. *Lablab* seeds have low human preference for food unlike soybean and groundnut cake resulting in their comparatively lower prices. The properly processed seeds have great potential in monogastric nutrition (Bawa, 2003). Extensive works have been done in the past on the use of *Lablab* forage as protein supplements for ruminants (Umunna *et al*., 1995; Otaru *et al*., 1998).

Basic engineering information on crops is necessary for optimal design of equipments. Such basic information is required not only by engineers but also by food scientists, processors and breeders (Mohsenin, 1980). Data on physical properties are important in the design of a specific machine or analysis of the behavior of products in order to perform various post harvest operations (Singh et al., 2004). Grading of fruits is based on the physical characteristics like size and shape. The size of fruits is essential for uniformity and packing in standard cartons while the bulk density, true density and porosity

are useful in storage, transport and separation systems (Kachru *et al*., 1994). Aviara *et al*., (1999) noted that the moisture dependent characteristics of physical properties have effect on the adjustment and performance of agricultural product processing machines. They further noted that the optimum performance of machines could be achieved at a specific range of moisture contents. It has been reported that the knowledge of physical properties and their dependence on the moisture content are useful for the design and development of methods and equipment (Oje, 1993; Visvanathan *et al*., 1996). The handling losses during threshing are reported to be influenced by the size and shape of agricultural materials. Moisture content also has a great influence in threshing, separation, cleaning and grading operations. The axial dimensions of agricultural product determine the size while its volume determines the shape (Irtwange and Igbeka, 2002).

Despite the increasing interest in *Lablab*, little is known on the basic physical characteristics of the seeds. In order to design post harvest handling and processing machines for *Lablab*, it is necessary to determine the effect of moisture content on some physical characteristics of the seeds such as size and shape, sphericity, roundness, porosity, true density, bulk density, mass and volume in the moisture range between 9.7 to 29 % wet basis (w.b.).

2. MATERIALS AND METHODS

2.1 Samples

Two varieties of *Lablab* seeds, 'Rongai' and 'Highworth' with 3.5 kg of each, obtained from the National Animal Production Research Institute, (NAPRI) Shika - Zaria, Nigeria, were manually cleaned by winnowing in the wind and hand sorted to eliminate dirts, stones, immature seeds and other foreign materials. Different moisture levels were obtained by soaking different bulk samples of *Lablab* in calculated quantity of water for a period between 30 minutes and two hours, followed by spreading out in thin layer to dry in natural air in the room for about eight hours. The desired moisture contents of samples were prepared by adding certain amount of water as calculated from the following relationship (Sacilik *et al*., 2003; Isik, 2007):

$$Q = \frac{W_i \left(M_f - M_i \right)}{100 - M_f}$$
(1)

Where

W_i = initial mass of sample, g.

M_i = initial moisture content of sample, % w.b.

M_f = final moisture content of sample, % w.b.

Before the tests, required quantity of seeds were taken from the Thermocool (T 200) refrigerator and allowed to equilibrate to room temperature for about 1 hr. The moisture contents in the range of 10.2 % to 22.6 % w.b. for 'Highworth' seeds and 9.7 % to 29 % w.b. for 'Rongai' seeds were used in the experiments. All measurements were performed at room temperatures between 27 ^{o}C and 30 ^{o}C.

2.2 Moisture Content

The moisture content (MC) of whole seeds was determined using the procedure detailed by Henderson et al., (1997). Five grams of seed samples from each variety were oven dried at 130 $^{\circ}$C for 24 hours (ASAE, 2003). The weight loss of samples was recorded and the moisture content was determined in percentages. This procedure was replicated three times. The average moisture content was calculated using the relationship:

$$MC_{wb}\% = \frac{W_i - W_d}{W_i} \cdot 100 \qquad (2)$$

Where

MC_{wb} = moisture content, % w.b.
W_i = initial mass of sample, kg.
W_d = dried mass of sample, kg.

2.3 Size and Shape

To determine the size and shape of the seeds, three samples were randomly drawn from the bulk sample. From each of the samples, 150 seeds were randomly picked and mixed together and the 450 seeds thus obtained from the three samples were thoroughly mixed. Finally, 100 seeds were randomly selected at each moisture content level. For each individual seed, three principal dimensions, namely length (L), width (W) and thickness (T) were measured using vernier caliper (with 0.001mm accuracy). Figure 1 shows the different geometrical dimensions of *Lablab* seeds. The geometric mean diameter (G_m) and arithmetic mean diameter (d_e) were calculated based on three dimensions using equations 3 and 4 given by Mohsenin (1980) while the equivalent diameter (D_E) was calculated using the mathematical expression for ellipsoidal bodies (Ciro,1997; Perez- Alegria *et al*., 2001):

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

$$d_e = \frac{L + W + T}{3} \qquad (4)$$

$$D_E = \frac{F_1 + F_2 + F_3}{3} \qquad (5)$$

Where

$$F_1 = \text{Arithmetic mean diameter} = \frac{L + W + T}{3}, \text{mm} \qquad (6)$$

$$F_2 = \text{Geometric mean diameter} = (LWT)^{1/3}, \text{mm} \qquad (7)$$

$$F_3 = \text{Square mean diameter} = \left(\frac{LW + WT + TL}{3}\right)^{1/3}, \text{mm} \qquad (8)$$

Where F_1, F_2, F_3 are linear diameters (mm), L is length (mm), W is width (mm) and T is thickness (mm) of the *Lablab* seed.
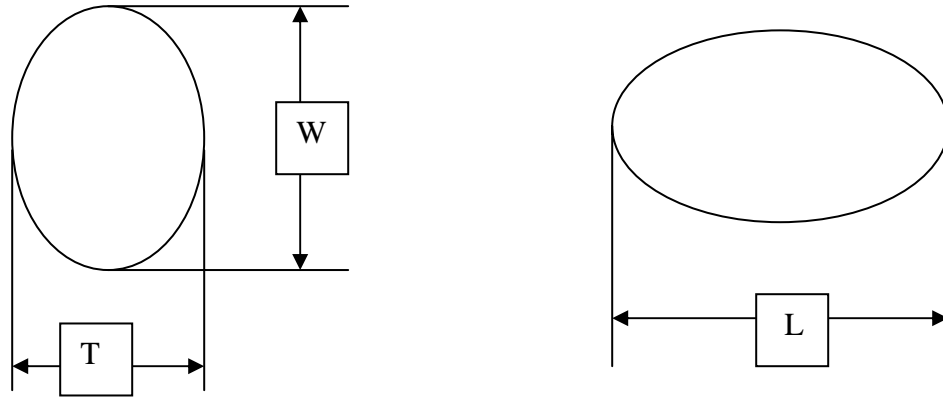
Figure 1. Different geometrical dimensions of *Lablab* seed

The sphericity (Q) is defined as the ratio of surface area of sphere having the same volume as that of seed to surface area of seed was determined using:

$$Q = \frac{(LWT)^{1/3}}{L} \qquad (9)$$

2.4 Roundness

Lablab seeds were placed on the surface of an overhead projector, (Model 316/2560, Tecquipment Ltd., England), in their natural rest position. The images were projected onto a vertical screen about 3 meters away. The lens was focused to obtain sharp image of the boundary of the grain on a graph paper. The outlines of projected images were traced on a graph paper. A millimeter scale was also traced to determine the magnification factor.

The projected area was estimated by counting squares within the traced boundary. The total number of squares was multiplied by the area of a graph square to get total area of projected boundary. The calculated area obtained was divided by the magnifications factor to get the projected area.

The traced projected outline of each seed at different moisture contents was used to estimate the roundness of the two varieties of *Lablab* seed. This was done by drawing the smallest circumscribing circle round the traced projected outlines and the area of the circle was calculated. Roundness, (R) was calculated using the relationship given by Mohsenin (1980):

$$R = \frac{A_p}{A_c} \qquad (10)$$

Where

A_p = largest projected area of object in natural rest position, mm^2
A_c = area of the smallest circumscribing circle, mm^2

2.5 Seed Mass

The individual seed mass was measured using a Mettler electronic balance (Sartorius 2355, Max 160 g, d= 0.001g). One hundred replications were taken for each variety at the different moisture contents, respectively.

2.6 Seed Volume

The volume of the seeds was determined by water displacement method. Seeds for mass measurement were placed inside a polyethylene bag and immersed in eureka can. The volume of the polyethylene bag was obtained with the aid of a sinker. The amount of water displaced when *Lablab* seeds were submerged was measured using a 50 ml measuring cylinder. The volume of the seeds was determined as the difference in water level minus the volume of the polyethylene. The representative value for individual seed was the average of 100 replications for each variety at the different moisture contents, respectively.

2.7 True Density

The true (particle) density (ρ_t) of the individual seed was calculated by dividing mass of seed by volume of seed obtained by water displacement.

$$\rho_t = \frac{M}{V}$$ (11)

Where
ρ_t = true density, g/cm^3
M = mass of individual seed, g
V = volume of water displaced by one seed, cm^3

2.8 Bulk Density

The bulk density (β) of *Lablab* seed was determined by filling a container with seed from a height of 150 mm at a constant rate and weighing the contents. The volume of the container was estimated by filling the container with water and measuring it with 50 ml measuring cylinder. The bulk density of the two varieties of *Lablab* was calculated as:

$$\beta = \frac{m}{V_c}$$ (12)

Where
β = bulk density, g/cm^3
m = mass of seed, g
V_c = volume of container, cm^3

2.9 Porosity

The porosity (ψ) of the seed at different moisture contents was calculated from the average values of bulk density and true density using the relationship:

$$\psi = \left(1 - \frac{\beta}{\rho_t}\right)100 \qquad (13)$$

Where

ψ = porosity, %
ρ_t = true density, g/cm^3
β = bulk density, g/cm^3

2.10 Statistical Analysis

The effect of moisture content on some physical properties of two varieties of *Lablab* such as sphericity, roundness, porosity, true density, bulk density, mass and volume were investigated using linear regression analysis to establish their relationship. Data collected were analyzed using General Linear Model (GLM) procedure of Statistical Analysis System (SAS, 1989) was used to analyze the data.

3. RESULTS AND DISCUSSION

3.1 Size and Shape

The results of mean axial dimensions of *Lablab* seed at different moisture contents are presented in table 1. The table shows that the three axial dimensions increased with moisture content in moisture range of 9.7 to 29 % w.b. It was observed that size and diameters of *Lablab* seed increased with increasing moisture content. The length of 'Rongai' seeds increased from 0.926 mm at 9.7 % w.b. to 1.039 mm at 29 % w.b. (12 % increase in length). Length of 'Highworth' seeds increased from 1.054 mm at 10.2 % w.b. to 1.113 mm at 22.6 % w.b. (6 % increase in length). Width of 'Rongai' seeds increased from 0.739 mm at 9.7 % w.b. to 0.807 mm at 29 % w.b. (9 % increase in width). Width of 'Highworth' seeds increased from 0.740 mm at 10.2 % w.b. to 0.768 mm at 22.6 % w.b. (4 % increase in width). The thickness for 'Rongai' seeds increased from 0.539 mm at 9.7 % w.b. to 0.588 mm at 29 % w.b. (9 % increase in thickness). Thickness of 'Highworth' seeds increased from 0.430 mm at 10.2 % w.b. to 0.450 mm at 22.6 % w.b. (5 % increase in thickness). The arithmetic mean diameter, geometric mean diameter and equivalent diameter of the three principal axes are also presented in table 1. There was 10 % and 5 % increase in the arithmetic mean diameter, geometric mean diameter and equivalent diameter for 'Rongai' seed and 'Highworth' seed varieties, respectively. It appears that 'Rongai' variety has a capacity to absorb more water and increase laterally than 'Highworth' variety. Irtwange and Igbeka (2002) and Aviara et al., (2005b) also observed similar trend for African yam bean and sheanut, respectively. The threshing cylinder-screen clearance is determined by these parameters. If the clearance is large, there will be under threshing while small clearance may result in excessive damage due to crushing.

Table 1. Mean axial dimensions of *Lablab* seeds at different moisture contents.

Variety	Moisture content, % w.b.	Length* mm	Width* mm	Thickness* mm	Arithmetic mean diameter, mm	Geometric mean diameter, mm	Equivalent diameter, mm
'Rongai' (White)	9.7	0.926 (0.0960)	0.739 (0.037)	0.539 (0.065)	0.735	0.717	0.726
	21.1	0.996 (0.084)	0.775 (0.038)	0.568 (0.067)	0.780	0.760	0.777
	23.9	1.028 (0.092)	0.781 (0.047)	0.573 (0.071)	0.794	0.772	0.783
	29	1.039 (0.085)	0.807 0.040)	0.588 (0.064)	0.811	0.790	0.801
'Highworth' (Black)	10.2	1.054 (0.105)	0.740 (0.032)	0.430 (0.033)	0.741	0.695	0.718
	13.4	1.091 (0.105)	0.755 (0.034)	0.450 (0.040)	0.765	0.718	0.742
	15.7	1.106 (0.063)	0.760 (0.028)	0.445 (0.042)	0.770	0.721	0.746
	22.6	1.113 (0.081)	0.768 (0.040)	0.450 (0.031)	0.777	0.727	0.752

* Mean of 100 samples.
Standard deviations are in parenthesis.

3.2 Sphericity

The sphericity of *Lablab* seed decreased with increasing moisture content as it is shown in figure 2. The sphericity of *Lablab* seeds decreased from 0.774 to 0.760 for 'Rongai' between 9.7 and 29 % w.b. and 0.659 to 0.653 for 'Highworth' between 10.2 and 22.6 % w.b. Sphericity values of most agricultural produce has been reported to range between 0.32 and 1.00 (Mohsenin, 1970; Irtwange and Igbeka, 2002).
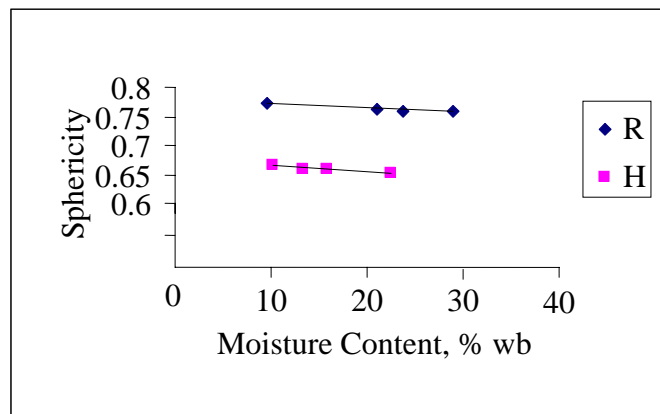
Figure 2. Effect of moisture content on sphericity of *Lablab* seeds

The regression equation of the relationship between sphericity (S) and moisture content is represented by:

$$S_R = 0.7806 - 0.0008M \qquad (14)$$
$$S_H = 0.6754 - 0.001M \qquad (15)$$

The coefficients of determination (R^2) were 0.92 and 0.88 for 'Rongai' and 'Highworth', respectively. A similar decreasing trend was reported by Irtwange and Igbeka (2002) for African yam bean and Isik (2007) for round red lentil. The sphericity has practical application in the design of processing and storage equipment, especially in handling operations such as conveying and discharge from chutes (Irtwange and Igbeka, 2002).

3.3 Roundness

The roundness of *Lablab* seed decreased with increasing moisture as it is given in figure 3. The roundness of 'Rongai' seeds decreased from 0.917 at 9.7 % w.b. to 0.896 at 29 % w.b. while that of 'Highworth' seeds decreased from 0.820 at 10.2 % w.b. to 0.803 at 22.6 % w.b.
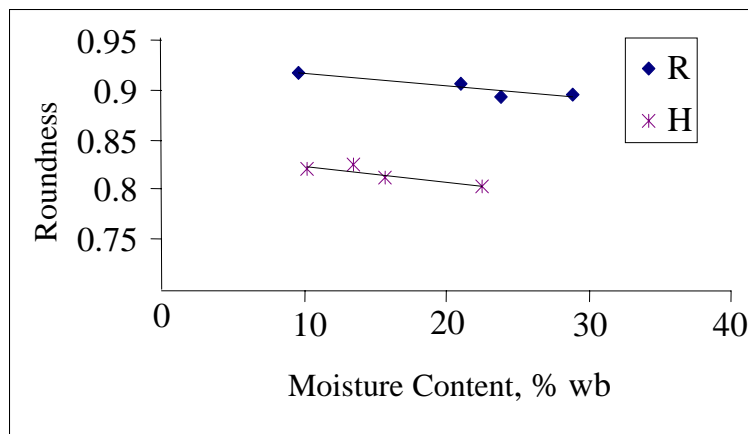

Figure 3. Effect of moisture content on roundness of *Lablab* seeds

This parameter was negatively correlated with moisture content like sphericity. The regression equations of the linear relationship between roundness (R) and moisture content are given as:

$$R_R = 0.9286 - 0.0012M \qquad (16)$$
$$R_H = 0.84 - 0.0016M \qquad (17)$$

The coefficients of determination (R^2) obtained were 0.79 and 0.77 for 'Rongai' and 'Highworth' seeds, respectively.

3.4 Seed Mass

The seed mass of *Lablab* seeds increased with increasing moisture content as it is given in figure 4. Mass of 'Rongai' seeds increased from 0.240 g at 9.7 % w.b. to 0.316 g at 29 % w.b. and that of 'Highworth' seeds increased from 0.229 g at 10.2 % w.b. to 0.283 g at 22.6 % w.b. This behavior may be due to increase in water content by weight as a result of increase moisture content which result in increase in size (Irtwange and Igbeka, 2002).
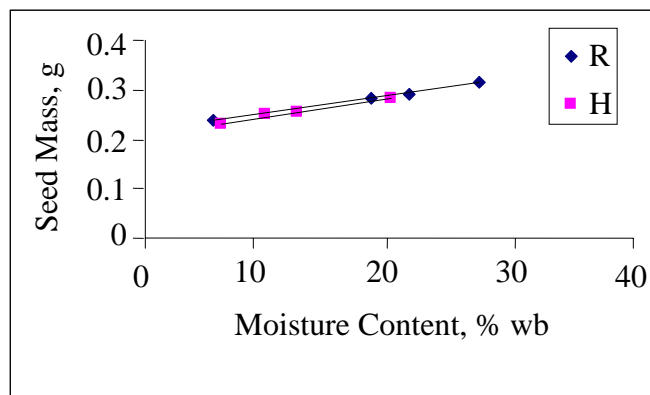

Figure 4. Effect of moisture content on seed mass of *Lablab* seeds

Linear regression relationship for mass (M) is depicted by the following expressions:

$$M_R = 0.2019 + 0.0038M \qquad (18)$$
$$M_H = 0.1886 + 0.0042M \qquad (19)$$

The coefficients of determination (R^2) obtained were 0.99 for 'Rongai' and 'Highworth' seeds, respectively. Similar trend was reported by Irtwange and Igbeka (2002) for African yam bean, Kaleemullah and Gunasekar (2002) for arecanut, Aviara *et al*., (2005b) for sheanut, Isik (2007) for round red lentil grain and Simonyan *et al*., (2007) for samaru sorghum 17. It has been reported that practical application of seed mass is in the design of equipment for cleaning, separation, conveying and elevating unit operations.

3.5 Seed Volume

The volume of *Lablab* seed increased with increasing moisture content as it is shown in figure 5. The volume of 'Rongai' seeds increased from 0.244 cm^3 at 9.7 % w.b. to 0.54 cm^3 at 29 % w.b. while 'Highworth' seeds increased from 0.108 cm^3 at 10.2 % w.b. to 0.2 cm^3 at 22.6 % w.b.
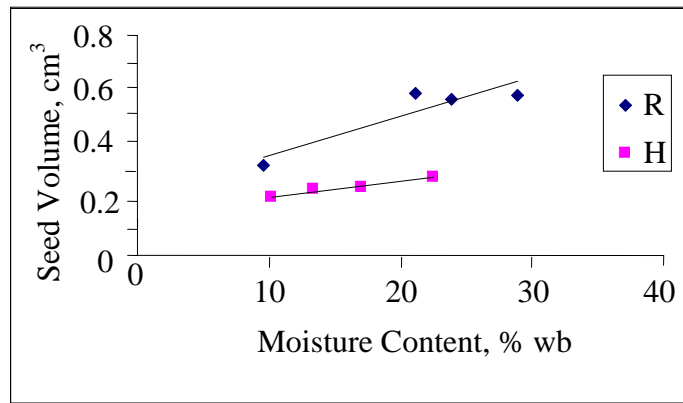
Figure 5. Effect of moisture content on seed volume of *Lablab* seeds

The linear relationship between the volume (V) and moisture content can be represented by the regression equations:

$$V_R = 0.1193 + 0.0167M \qquad (20)$$
$$V_H = 0.0417 + 0.0069M \qquad (21)$$

The coefficients of determination (R^2) were 0.83 and 0.94 for 'Rongai' and 'Highworth' seeds, respectively. Similar trends have been reported for African yam bean, sheanut, and millet by Irtwange and Igbeka (2002), Aviara et al., (2005b) and Ndirika and Oyeleke (2006), respectively. It has been reported that the practical significance of volume is in the design of sowing and sizing machinery.

3.6 True (Particle) Density

The true (particle) density of the *Lablab* seed increased with increasing moisture content as it is given in figure 6. True density of 'Rongai' seeds increased from 1.394 g/cm^3 at 9.7 % w.b. to 1.526 g/cm^3 at 29 % w.b. while that of 'Highworth' seeds increased from 1.385 g/cm^3 at 10.2 % w.b. to 1.537 g/cm^3 at 22.6 % w.b. The increasing trend was expected since both the mass and volume on which particle density is based increased with increasing moisture content.
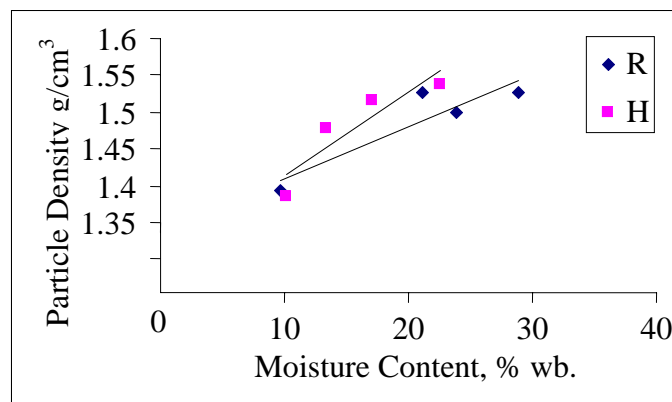

Figure 6. Effect of moisture content on particle density of *Lablab* seeds

The relationship between the particle density (P) and moisture content can be represented by the regression equations:

$$P_R = 1.3399 + 0.007M \qquad (22)$$
$$P_H = 1.2066 + 0.0115M \qquad (23)$$

The coefficients of determination (R^2) were 0.83 and 0.82 respectively for 'Rongai' and 'Highworth' seeds. Similar results were reported by Perez-Alegria et al., (2001) for parchment coffee bean, Ozarslan (2002) for cotton seed, Aviara *et al*., (2005a) for balanites aegypticiaca nuts, Aviara *et al*., (2005b) for sheanut and Isik (2007) for round red lentil grain. The particle density of agricultural products have been reported to play significant importance in the design of silos and storage bins, maturity and quality evaluation of products which are essential to grain marketing (Irtwange and Igbeka,2002).

3.7 Bulk Density

The bulk density of *Lablab* seed decreased with increase in moisture content as it is shown in figure 7. For the 'Rongai' seed variety, it decreased from 0.781 g/cm^3 at 9.7 % w.b. to 0.690 g/cm^3 at 29 % w.b. while for 'Highworth' seeds decreased from 0.803 g/cm^3 at 10.2 % w.b. to 0.717 g/cm^3 at 22.6 % w.b.
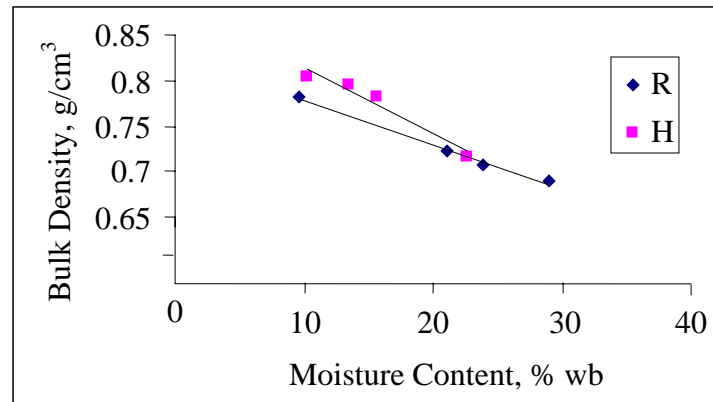

Figure 7. Effect of moisture content on bulk density of *Lablab* seeds

The regression equation for bulk density (B) was of the form:

$$B_R = 0.8257 - 0.0048M \qquad (24)$$
$$B_H = 0.8859 - 0.0072M \qquad (25)$$

The coefficients of determination (R^2) were 0.99 and 0.95 for 'Rongai' and 'Highworth', respectively. Similar trend was reported for chickpea seeds by Konak *et al*., (2002), African yam bean by Irtwange and Igbeka (2002), arecanut kernels by Kaleemullah and Gunasekar (2002) and round red lentil grains by Isik (2007). Bulk density has been reported to have practical applications in the calculation of thermal properties in heat transfer problems, in determining Reynolds number in pneumatic and hydraulic handling of materials and in predicting physical structure and chemical composition (Irtwange and Igbeka, 2002).

3.8 Porosity

The porosity of *Lablab* seeds decreased with increasing moisture content as it is given in figure 8. Porosity of 'Rongai' seeds decreased from 0.649 % at 9.7 % w.b. to 0.534 % at 29 % w.b. while that of

'Highworth' seeds decreased from 0.335 % at 10.2 % w.b. to 0.173 % at 22.6 % w.b. The decrease in porosity with increase in moisture was also reported by Irtwange and Igbeka (2002) for African yam bean. It was observed that as the seed gains moisture, its volume increases, increasing the size and shape which creates a more intimate contact with each other, thereby reducing the pore space.
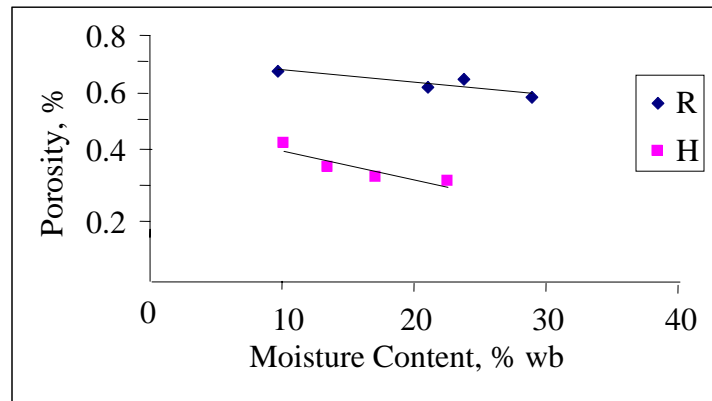

Figure 8. Effect of moisture content on porosity of *Lablab* seeds

The regression equation of the relationship between porosity (P) and moisture content can be expressed as:

$$P_R = 0.7022 - 0.0052M \tag{26}$$
$$P_H = 0.4257 - 0.0123M \tag{27}$$

The coefficients of determination (R^2) were 0.75 and 0.78 for 'Rongai' and 'Highworth' seeds, respectively. The same decreasing trend has been reported for African yam bean by Irtwange and Igbeka (2002).

4. CONCLUSIONS

1. The size and diameters, volume and true (particle) density of *Lablab* seeds increased with increasing moisture content.
2. The sphericity, roundness, seed mass, bulk density and porosity of *Lablab* seeds decreased with increasing moisture content.

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