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Research Article

PHYSICAL PROPERTIES OF MAIZE GRAINS

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Abstract- The research was conducted on Effect of moisture content on physical properties of maize grains (*Zea mays L*) was investigated in College of Agricultural Engineering during the year 2012-2013. The physical properties of the grain samples were determined at the desired moisture content levels of 12, 14, 16, 18 and 20 (% w.b.). The average three axial dimensions, sphericity, surface area, volume, thousand grain weight, true density, porosity and the static coefficient of friction were found to be increased and the bulk density was found to be decreased with increase in moisture content from 12 to 20 (% w.b.); all at an average temperature of 30°C. All these properties followed an increasing trend with the increase in moisture content, each showed a high correlation coefficients.

Keywords- Physical properties, Maize, Moisture content, Bulk density, Porosity, True density

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Introduction

Maize (*Zea mays L*) is also known as corn, is the world's third most important cereal crop after wheat and rice. It has very high yield potential and is commonly known as "Queen of cereals". Maize contains about 10% proteins, 4% oil, 70% carbohydrates, 2.3% crude fiber, 10.4% albuminoides and 1.4% ash. Maize has significant quantities of vitamin A, nicotinic acid, riboflavin and vitamin E. World produces about 856 million tons of maize, whereas India produces about 21.76 million tons (2011-12). It is grown over an area of 8.33 lakh hectares in Andhra Pradesh with total production of 36.58 lakh tones. [1]

Information on physical properties of maize, like other agricultural materials, is necessary to design equipment for grading, handling, processing and storage *etc*. To design machines for cleaning, grading, sorting and packing *etc*., size and shape such as geometric mean diameter and sphericity are necessary to be known. The surface area and porosity are required to evaluate the rate of heat transfer for heating and drying and thus to design heat exchangers and driers *etc*. Bulk density, true density and porosity are required for the design of aeration, storage, transport and separation systems. True and bulk density data have also been used to determine the dielectric properties of cereal grains. It has been established that the properties of crops vary with their moisture contents. [4]. In recent years, physical properties have been studied for various crops such as barley grains, pearl millet seeds, cucurbit seeds, pigeon pea, and wheat. [16, 10, 8, 3, 6]. However, no information on physical properties of maize varieties grown in Andhra Pradesh is available in the literature.

The present study discusses the variations in some physical (three axial dimensions, sphericity, surface area, volume, thousand grain weight, bulk density, true density, porosity and the static coefficient of friction) properties of maize grown in Andhra Pradesh with changes in moisture content.

Material and Methods

Maize cobs were procured from Agricultural college farm, Bapatla, A.P., India, to carry out the research work. The maize cobs were manually shelled and cleaned to remove all foreign matter such as surface dust, dirt, stores and chaff. The initial moisture content of the samples was determined for all the samples using standard procedure [2]. The maize samples of 100 grams were taken and the desired moisture content of samples were achieved by adding "Q" amount of distilled water, as calculated from the following relationship

$$Q = \frac{W_t(M_f - M_i)}{(100 - M_f)} \quad \text{.............. [1]}$$

Where, Q = Weight of required water (g), W_t = Total weight of sample (g), M_f = Final moisture content (%) and M_i = Initial moisture content (%).

The samples were then transferred to separate polyethylene bags, and the bags were hermatically sealed. The samples were kept at 5 °C in a refrigerator for a week to enable the moisture to be distributed uniformly throughout each sample. Before starting a test, the required quantities of the samples were taken out of the refrigerator and allowed to warm up to the room temperature of 30°C for about 2 h. This rewetting technique was carried out to attain the desired moisture content in the grain samples. All the physical properties of the grain samples were determined at the desired moisture content of 12, 14, 16, 18 and 20 (% wb) [16].

Five replications of each test were made at each moisture level. The length, width, thickness and mass of maize grains were measured on randomly selected 100 maize grains for each moisture content. The length, width and thickness of materials were measured using a digital caliper with an accuracy of 0.01 mm. [4].

The sphericity Φ, surface area and volume of maize grains were calculated by using the following relationship [9].

Sphericity, S_p = $\frac{(LWT)^{1/3}}{L}$ ....[2]

Surface area = ΠD_g^2 ....[3]

Volume = $0.25[\frac{\pi}{6}L(W+T)^2]$ ....[4]

Where, L = Length of the maize grain, (mm), W = Width of the maize grain, (mm), T = Thickness of the maize grain.

Thousand grain weight was measured by weighing 250 grains in an electronic balance with an accuracy of 0.01g and then multiplied by 4 to give weight of 1000 kernels [4].

The true density was defined as the ratio between the mass of maize grains and the true volume of the grains, and determined using the toluene (C_7H_8) displacement method. Toluene was used instead of water because it is absorbed by grains to a lesser extent. The volume of toluene displaced was found by immersing a weighted quantity of maize grains in the measured toluene [4]. The average bulk density of the maize samples were determined by using the standard test weight procedure by filling a container of 1000 ml with samples of 100 ml by tapping twice for uniform packing and to minimise wall effect and then weighed the contents [14]. The porosity was calculated from bulk and true densities by the following equation [9].

Porosity = $(1-\frac{\text{Bulk density}}{\text{True density}}) \times 100$. ....[5]

The angle of repose is the angle compared to the horizontal at which the material will stand when piled. This was determined by using the apparatus shown in [Fig-1], consisting of a plywood box of 60 × 60 × 60 mm and two plates, provided with fixed and adjustable plates. The box was filled with the sample, and then the adjustable plate was inclined gradually allowing the grains to follow and assume a natural slope, this was measured as emptying angle of repose [17].

The static coefficients of friction of maize grains against three different surfaces, namely, plywood, glass and mild steel sheet were determined [17]. The coefficient of friction was calculated from the following relationship:

$\mu = \tan\alpha$ ....[6]

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

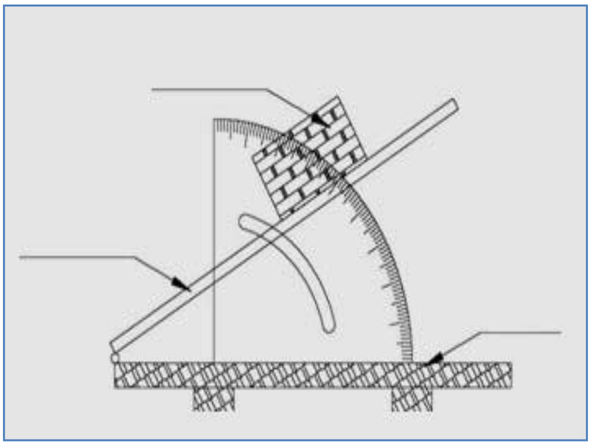

Fig-1 Apparatus for measuring empting angle of repose

Results and Discussion

Grain dimensions

Average values of the three principal dimensions of maize grain, namely, length, width and thickness were determined at different moisture contents are presented in [Table-1]. Each principal dimension appeared to be linearly dependent on the moisture content is shown in [Fig-2]. Very high correlation was observed between the three principal dimensions and moisture content indicating that upon moisture absorption, the maize grain expands in length, width and thickness within the moisture range of 12 to 20 (% wb). The average length, width and thickness of the 100 grains varied from 11.01 to 11.29 mm, 7.91 to 8.35 mm and 3.83 to 4.48 mm, respectively as the moisture content increased from 12 to 20 (% wb).

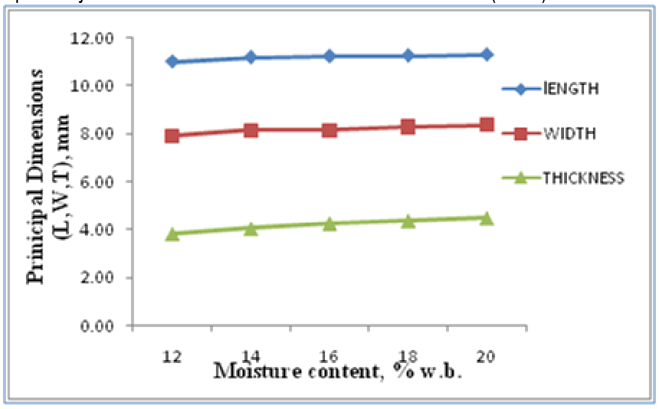

Fig-2 Effect of moisture content on principal dimensions of maize

Sphericity

The values of sphericity were calculated individually with [Eq-2] by using the data on geometric mean diameter and the major axis of the grain and the results obtained are presented in [Table-1]. The sphericity of the maize grain increased from 0.63 to 0.67 as the moisture content increased from 12 to 20% w.b. The relationship between sphericity (ϕ) and moisture content (*M*) appears linear and can be represented by the following equation:

$\phi = 0.009M + 0.620$ $R^2 = 0.997$ ......[7]

The increasing trend for sphericity with moisture content have been observed for maize and paddy grains [4,12,18].

Thousand grain mass

The thousand grain mass of maize increased linearly from 232.87 to 270.42 g as the moisture content increased from 12 to 20 (% wb) [Table-1]. This relationship between 1000 grain mass (m_{1000}) and the moisture content (*M*) can be represented by the following equation:

$m_{1000} = 9.537\ M + 227.3$ $R^2 = 0.919$ .....[8]

The increasing trend for thousand grain weight with increase in moisture content have been observed for pearl millet, corn, sweet corn and pigeon pea [10,12,5,3].

Surface area

The surface area of the grain was calculated by using [Eq-3] and presented in [Table-1]. The surface area of maize grain increases linearly from 150.92 to 177.32 mm^2 when the moisture content increased from 12 to 20 (% wb). The variation of moisture content (*M*) and surface area (*S*) can be expressed mathematically as follows:

$S = 6.413M + 146.6$ $R^2 = 0.971$ ......[9]

The increasing trend in surface area with increase in moisture content have been observed for wheat, barnyard millet, barely and maize [6,13,16,12].

Volume

The volume of the grain was calculated by using [Eq-4] and presented in [Table-1]. The volume of maize grain increases linearly from 198.42 to 244.17 mm^3 when the moisture content increased from 12 to 20 (% wb). The variation of moisture content (*M*) and surface area (*S*) can be expressed mathematically as follows:

$V = 11.01M + 191.2$ $R^2 = 0.970$ ...[10]

The increasing trend in surface area with increase in moisture content have been observed for wheat, barnyard millet, barely and maize [6,13,16,12].

Bulk density

The grains bulk density at different moisture levels varied from 758.80 to 721.87 kg/m^3 indicated a decrease in bulk density with an increase in moisture content from 12 to 20 (% wb). This was due to the fact that an increase in mass owing to moisture gain in the sample was lower than accompanying volumetric expansion of the bulk. The bulk density (ρ_b) of the grains was found to have the following linear relationship with the moisture content (M):

$\rho_b = -9.402M + 770.2$ $R^2 = 0.977$ ...[11]

Table-1 *Physical properties of maize grains at different moisture contents*

Moisture content, %w.b	Axial Dimensions			Average diameters		Sphercity	1000 grain weight	Surface area	Volume	Bulk density	True density	Porosity	Angle of repose
	Length, L	Width, W	Thickness, T	Arithmetic mean	Geometric mean								
12	11.00	7.91	3.83	7.58	6.93	0.63	232.867	150.92	198.42	758.80	1204.30	36.99	25.56
14	11.18	8.14	4.04	7.79	7.16	0.64	247.033	161.13	217.01	754.45	1213.33	37.82	27.67
16	11.22	8.14	4.27	7.88	7.31	0.65	262.200	167.59	226.28	740.60	1220.63	39.33	30.00
18	11.25	8.28	4.37	7.97	7.41	0.66	267.300	172.45	235.64	734.30	1224.18	40.02	33.00
20	11.29	8.35	4.50	8.05	7.51	0.67	270.420	177.32	244.17	721.87	1228.79	41.25	34.78

True density

The true density of maize grains at different moisture contents varied from 1204.30 to 1228.79 kg/m^3, [Table-1]. The effect of moisture content on true density of the grains showed a increase with increasing moisture content. The moisture (M) dependence of the true density (ρ_t) was described by a linear equation as follows:

$\rho_t = 5.982\ M + 1200.$ $R^2 = 0.965$ ...[12]

The increasing trends in true density with increase in moisture contents have been observed for rice, corn, sweet corn and barnyard millet and kernel. [7,125,13].

Porosity

Porosity was calculated through [Eq-5] by using the data on bulk and true densities of the maize grain and presented in [Table-1]. The variation of porosity with moisture content is shown in [Table-1]. The porosity was found to increase linearly from 36.99 to 41.25 in the specified moisture levels [Fig-3]. The relationship between porosity (ε) value and the moisture content (M) of the grains was obtained as:

$\varepsilon = 1.072\ M + 35.86$ $R^2 = 0.989$ ...[13]

The increasing trends in porosity with increase in moisture content have been observed for barely, Cucurbit seeds and rice [11,8,7]

Angle of Repose

The experimental results for the angle of repose with respect to moisture content are presented in [Table-1]. The values were found to increase from 25.56° to 34.78° in the moisture range of 12 to 20 (% wb). This increasing trend of angle of repose with moisture content occurs because surface layer of moisture surrounding the particle hold the aggregate of grain together by the surface tension [15]. The values of the angle of repose (θ) for maize grain bear the following relationship with its moisture content (M):

$\theta = 2.377M + 23.06$ $R^2 = 0.995$ ...[14]

The increasing trends in angle of repose with increase in moisture content have been observed for maize.

Static coefficient of friction

The static coefficients of friction of maize grain on three surfaces (mild steel sheet, plywood, and glass) against moisture content in the range of 12 to 20 (% wb) are presented in [Fig-3]. It was observed that the static coefficient of friction increased linearly with increase in moisture content for all contact surfaces. The reason for the increased friction coefficient at higher moisture content may be owing to the water present in the grain offering a cohesive force on the surface of contact [15]. Increases of 35.48, 32.47 and 24.93 % were recorded in the case of mild steel sheet plywood, and glass respectively, as the moisture content increased from 12 to 20 (% wb). The relationships between static coefficient of friction (μ) and the moisture content (M) on plywood (wd), glass (gl) and Mild steel (ms) can be represented by the following equations:

$\mu_{ms} = 0.066M + 0.413$ $R^2 = 0.999$ ... (15)

$\mu_{wd} = 0.065M + 0.432$ $R^2 = 0.981$ ... (16)

$\mu_{gl} = 0.037M + 0.405$ $R^2 = 0.991$ ... (17)

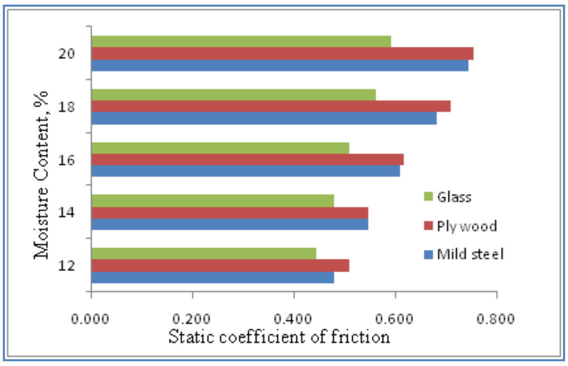

Fig-3 Effect of moisture content on static coeffient of friction for different surfaces of maize

Conclusion

The three axial dimensions, sphericity, volume, surface area and thousand grain weight were increased with increase in moisture content from 12 to 20% w.b. The true density and porosity of maize samples increased with increase in moisture content from 12 to 20% w.b., whereas bulk density decreased with increase in moisture content from 12 to 20% w.b. The angle of repose and static coefficient of friction of maize samples increased with increase in moisture content from 12 to 20% w.b. on all the three surfaces *viz.,* mild steel, plywood and glass

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