Study on Physical Properties of Indira Kodo-I (Paspalum Scrobiculatum L.) Millet

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Abstract- Kodo **millet (*Paspalum scrobiculatum* L.*)* is popularly comes in the category of coarse cereals and included in the broad category of cereals. *Kodo* millet is nutritionally superior to rice and wheat and presence of all the required nutrients, which make it suitable for industrial scale utilization in food stuff .It is also a good source of protein, carbohydrate and rich source of minerals, fibers, vitamins and micronutrients. Studies of engineering properties of variety Indira *Kodo*-I (*Paspalum scrobiculatum* L.) was conduct in moisture range from 8.19 to 12.71 per cent (db). It was found the length, width and thickness ranged from 2.61 to 2.74 mm, 1.96 to 2.23 mm and 1.33 to 1.45 mm, respectively. The length-breadth ratio ranged from 1.33 to 1.23, the size ranged from 1.90 to 2.07 mm, the Sphericity varied from 0.73 to 0.76. Surface area and volume ranged from 9.06 to 11.53 m^2, 2.59 to 3.46 m^3 respectively. It was further observed that the bulk density decreased from *Kodo* is 0.67 to 0.62 gml^{-1}, and true density increased from 1.20 to 1.24 gml^{-1}, porosity ranged from 43.99 to 50.27 per cent, the Angle of repose increased from 25°28' to 26°05'.**

Key words: Physical properties, Kodo millet, moisture content, surface area, volume,true density, bulk density, porosity, angle of repose, spherisity

I. INTRODUCTION

Araka or *Kodo* millet (*Paspalum scrobiculatum* L.) was domesticated in India almost 3000 years ago. It is found across the old world in humid habitats of tropics and subtropics. It is a minor grain crop in India, and an important crop in the Deccan plateau. Its cultivation in India is generally confined to Gujarat, Karnataka, Chhattisgarh, Eastern Madhya Pradesh and parts of Tamil Nadu. In recent years, millets are recognized as important substitutes for major cereal to cope up with worldwide food shortage and to meet the demand of increasing population of both developing and developed countries. *Kodo* millet *(Paspalum scrobiculatum* L.) and little millet *(Panicum miliare* L.) are classified as coarse grains and cultivated mostly in India, China, USSR, Japan and Africa [1]. *Kodo* grains are easily preserved and proved as a good famine reserve. *Kodo* grains contain 8.35% protein, 1.45% fat, 65.65% carbohydrate and 2.95% ash. It may be considered as nutria-cereal. Nutritionally it is comparable with other common cereals and in some respect it is superior to rice and wheat. The grain is recommended as a substitute for rice to the patients suffering from diabetes disease. *Kodo* grains provide cheap proteins, minerals and vitamins to poor people. India is world's lagers producers of millets having production of 10,000 MT in 2011-2012. Chhattisgarh is also major producing state of millet specially the Baster region having production of 64 MT in 2011-12 [2].Production of Small millets in India 461.30 MT and Chhattisgarh 25.10 MT 2014-2015[3]. The knowledge of physical properties of millet seeds and how these properties are affected by the moisture content is important for design of suitable equipment to handling, transporting, processing, and storing the grains.

II.MATERIALS & METHODS

The raw material *Kodo* was procured from S.G. College of Agriculture and Research Station, Jagdalpur (C.G.) for the present investigation. Grains were properly cleaned manually for removal of foreign matters such as dirt, stone, and chaff, immature and broken grain. Different properties of *Kodo* such as moisture content, size and shape, surface area, volume, sphericity, angle of repose, bulk density and true density were determined using standard techniques. In order to study the effect of moisture content on different physical and engineering properties of *Kodo* millet, the moisture content of the sample was determined.

Moisture content of the sample was determined by standard air oven method [4].The loss in weight was determined and moisture content was calculated using the following expression:

$$\text{Moisture content, \%(db)} = \frac{\text{Weight of moisture}}{\text{Weight of dry matter}} \times 100 \quad ..(1)$$

For the measurement of seed Length (L), Width (W) and Thickness (T), randomly 20 grains from each variety were selected for determination of L, W and T by using vernier caliper with a least count of 0.01mm.
Length-breadth ratio of the grains was determined using the following Formula:

$$\text{Length bredth ratio } = \frac{L}{B} \quad ...(2)$$

Where L = Length, mm; and b = breadth, mm;
For measuring the Surface area (S) of millet grain, the following formula was used [5].

$$S = \frac{\pi B L^2}{(2L - B)} \quad ...(3)$$

Where, B= $(WT)^{0.5}$, S = Surface area, mm^2; L = Length, mm; W= width, mm;
Volume (V) was determined using the formula, proposed by [5].

$$V = \frac{\pi B^2 L^2}{6(2L - B)} \quad ...(4)$$

Size of the seeds was calculated with the following formula proposed by [6].

$$S_z = (L \times W \times T)^{1/3} \quad ....(5)$$

Sphericity (Ø) is defined as the ratio of surface area (S) of having same volume (V) as that of the particle to the S of the particle. The sphericity is expressed in percent [6].

$$\emptyset = \frac{(L \times W \times T)^{1/3}}{L} \quad ...(6)$$

Bulk density (B_d) of paddy grains was determined by taking the weight of paddy in fixed volume [7].

$$B_d = \frac{W}{V} \quad ...(7)$$

The True density (T_d) is defined as the ratio of mass of grain to the solid volume occupied. It is determined using liquid displacement technique [7]

$$Td = \frac{M}{S} \quad ...(8)$$

Porosity was calculated as ratio of the difference in the grain and bulk densities to grain density and expressed in percentage [7].

$$\text{Porosity } (\varepsilon)\ \% = 1 - \frac{B_d}{T_d} \quad ...(9)$$

The angle of repose was measured by slump cone method [8]. A cylinder was filled up to top with sample and inverted on a plane (paper) surface. The paper was taken out gradually and cylinder was raised vertically, thus conical shape of the material was formed. Angle of repose was calculated by using the following expression [9].

$$\emptyset = \tan^{-1}\frac{2(H_a - H_b)}{D_b} \quad ....(10)$$

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III. RESULT AND DISCUSSION

The results of different physical properties of *Kodo* grain with variation in moisture content in the range of 8.19 to 12.71 per cent on dry basis are presented in the following sub-sections.

Table 1:- Physical Properties of *Kodo* Millet

Treatment	Moisture content %(db)	Length mm	Width mm	Thickness mm	Length breath ratio mm	Size mm	Sphericity
T_1	8.19	2.61^{d}	1.96^{c}	1.33^{c}	1.33^{a}	1.90^{c}	0.73^{c}
T_2	8.26	2.65^{c}	2.02^{bc}	1.37^{bc}	1.31^{ab}	2.00^{b}	0.73^{c}
T_3	9.21	2.69^{b}	2.11^{b}	1.41^{b}	1.27^{b}	2.00^{b}	0.74^{b}
T_4	9.63	2.72^{ab}	2.18^{ab}	1.41^{b}	1.25^{c}	2.03^{ab}	0.75^{ab}
T_5	12.71	2.74^{a}	2.23^{a}	1.45^{a}	1.23^{d}	2.07^{a}	0.76^{a}
	SE_m	0.007	0.011	0.011	0.008	0.006	0.003
	CD at 5%	0.025	0.0346	0.036	0.027	0.247	0.001

T_1= 20 min roasting T_2 = 24 h soaking T_3 = 30 h soaking T_4 = 10 min roasting T_5 = raw *Kodo*

Length, Width and Thickness

It was observed that the length of *Kodo* increased with increasing moisture content. The length of *Kodo* varied from 2.61 to 2.74 mm. With respect to moisture content similar trends were observed width and thickness of *Kodo* varied from 1.96 to 2.23 mm and 1.33 to 1.45 mm, respectively.This was due to the fact that with the increase in moisture content the length width and thickness of the grain increased upon swelling which turn in increased in length width and thickness shown in (Table1) and (Fig. 1)

A regression equation is observed with following relationship

$$L = 0.023\,M + 2.454 \qquad (R^2 = 0.691) \qquad \ldots (11)$$

$$W = 0.52\,M + 1.601 \qquad (R^2 = 0.744) \qquad \ldots (12)$$

$$T = 0.021\,M + 1.188 \qquad (R^2 = 0.746) \qquad \ldots (13)$$

Where, L = Length, mm; W = Width, mm; T = Thickness, mm; and M =Moisture content, % (db)

Similar increasing trends with increase in moisture content have been reported by [10] for millet and [11] for soybean, [12] for okra seed, [13] for soybean.

Length-breadth ratio

Length-breadth (L/B) ratio for *Kodo* grains varied from 1.33 to 1.23 mm .It was observed that with the increase moisture content the length-breath ratio of *Kodo* decreased. This result may be due to more expansion in breath as compared to the length with respect to moisture content. Shown in (Table1) and (Fig. 2)

The equation obtained can be represented as

$$L/B = -\,0.009\,M^2 - 0.218\,M + 2.477 \qquad (R^2 = 0.981) \qquad \ldots. (14)$$

Where, L/B = length and breadth ratio; and M = Moisture content % (db)

The negative sign shows the decrease in the length and breadth ratio in the experimental moisture range. Similar decreasing trends with increase in moisture content have been reported by [14] for *Kodo* millet.

Size

The size of *Kodo* increased from 1.90 to 2.07 mm. shown in (Table1) and (Fig. 3).This was due to the fact that with the increase in moisture content the size of the grain increased upon swelling, which turn in increased the diameters in all the three direction. The relationship between size (S_z) and moisture content represented by the following equation

$$Sz = 0.026\,M + 1.746 \qquad (R^2 = 0.601) \qquad \ldots (15)$$

Where, S_z = size mm; and M = moisture content %(db)

Similar increasing trends with increase in moisture content have been reported by [15] for wheat and [16] for finger millet.

Spherisity

The Spherisity of *Kodo* increases from 0.73 to 0.76 as the moisture content increased from 8.19 to 12.71 per cent (db). Shown in (Table1) and (Fig. 4)

$$\phi = 0.114\,M - 0.258 \quad (R^2 = 0.910) \quad \ldots. (16)$$

Where, ϕ = Spherisity of *Kodo;* and M = Moisture content, % (db).

Similar increasing trends with increase in moisture content have been reported by, [16] for finger millet, [11] for soybean and [10] for millet.

Surface area

Surface area of *Kodo* grains increased with the increase in moisture content. The value of Surface area was determined to be in the range of 9.06 to 11.53 m^2. Shown in (Table2) and (Fig. 5)

$$S = 0.420\,M + 6459 \qquad (R^2 = 0.652) \qquad \ldots (17)$$

Where, S = Surface area of *Kodo* and M = Moisture content, % (db)

Similar increasing trends with increase in moisture content have been reported by [10] for millet and [16] for finger millet.

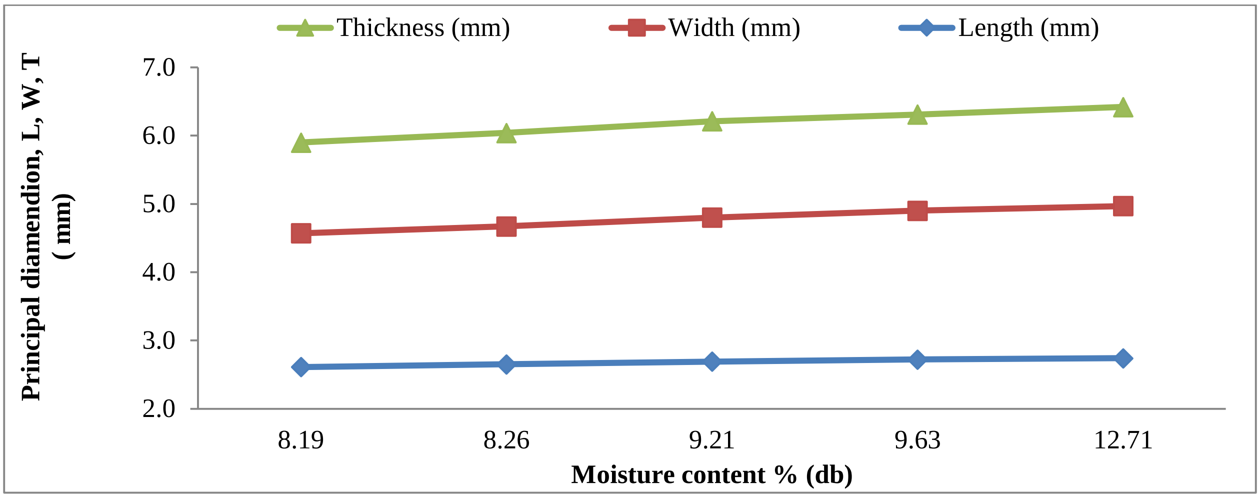

Fig.1: Effect of moisture content on Length Breadth and Thickness of *Kodo* grains

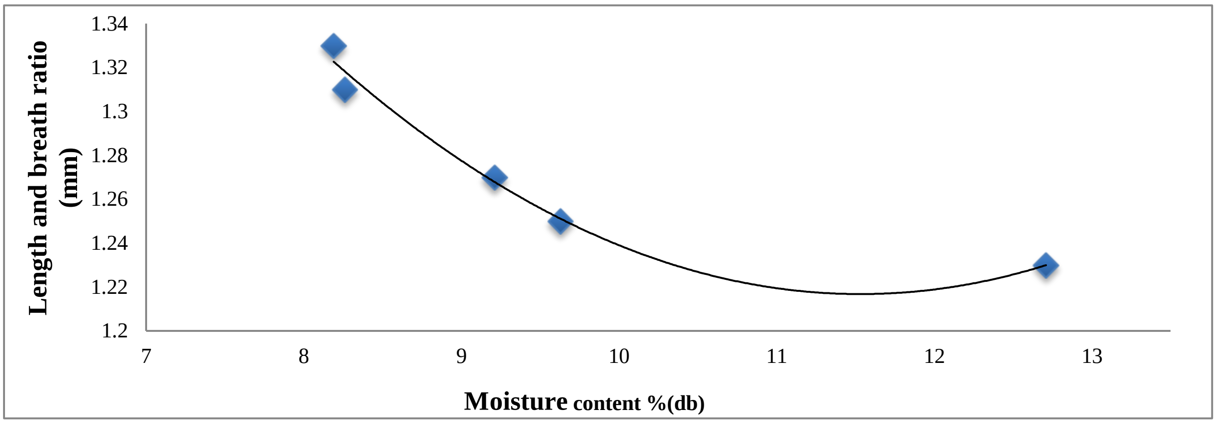

Fig. 2: Effect of moisture content on length and breadth ratio of *Kodo* grains

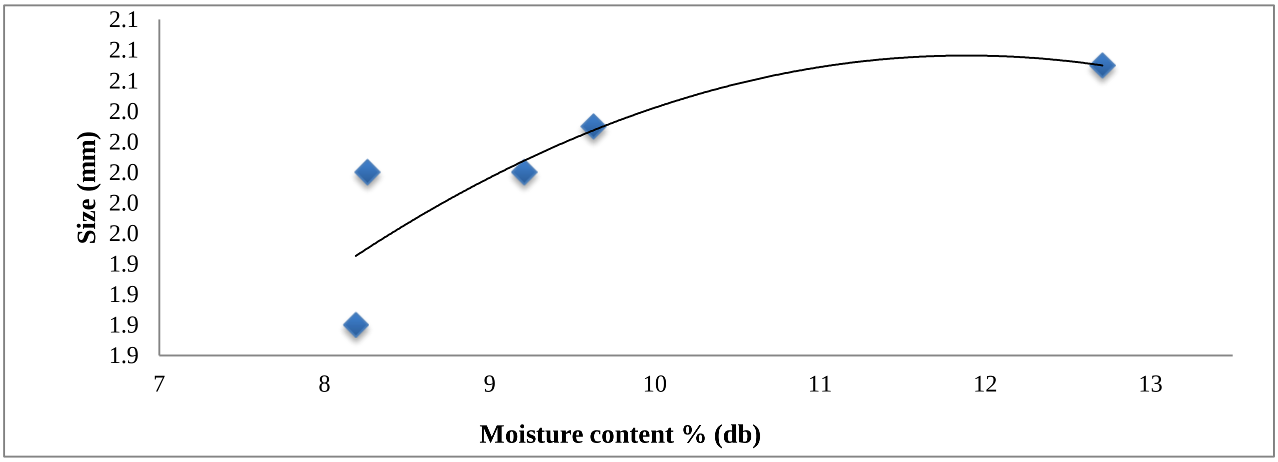

Fig. 3: Effect of moisture content on Size of *Kodo* grains

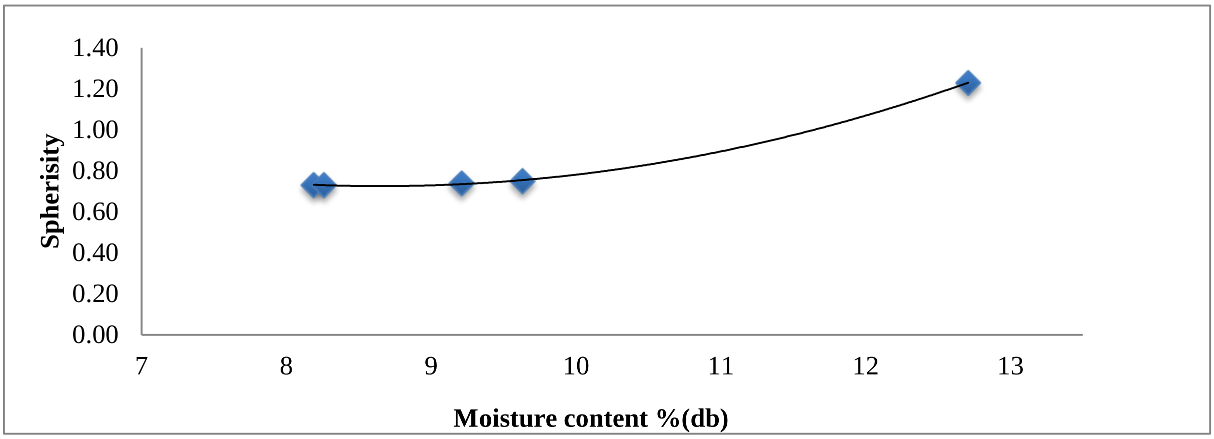

Fig.4: Effect of moisture content on Spherisity of *Kodo* grains

Table 2:-Physical Properties of *Kodo* Millet

Treatment	Moisture content %db	Surface area m^2	Volume m^3	Bulk density g/ml	True density g/ml	Porosity %	Angle of repose degree
T_1	8.19	9.06^{d}	2.59^{c}	0.67^{a}	1.20^{c}	43.99^{c}	25.28^{c}
T_2	8.26	10.08^{c}	2.79^{bc}	0.65^{ab}	1.22^{b}	46.57^{bc}	25.45^{bc}
T_3	9.21	10.74^{b}	3.09^{b}	0.64^{b}	1.22^{b}	47.97^{b}	25.72^{b}
T_4	9.63	11.06^{ab}	3.24^{ab}	0.64^{b}	1.24^{a}	48.65^{ab}	25.92^{ab}
T_5	12.71	11.53^{a}	3.46^{a}	0.62^{c}	1.24^{a}	50.27^{a}	26.05^{a}
	SE_m	0.073	0.035	0.005	0.007	0.600	0.039
	CD at 5%	0.024	0.115	0.016	NS	1.956	0.127

T_1= 20 min roasting T_2 = 24 h soaking T_3 = 30 h soaking T_4 = 10 min roasting T_5 = raw *Kodo*

Volume

The value of volume was determined to be in the range of 2.59 to 3.46 m^3. Statistical analysis showed the coefficient of variation as 2.016 percent in (Table2) and (Fig. 6). It can be observed that all the values are showing significant difference with each other.

$$V = 0.343\,M - 5.884 \quad (R^2 = 0.626) \quad \dots(18)$$

Where, V = Volume of *Kodo* and, M = Moisture content % (db)

Similar increasing trends with increase in moisture content have been reported by [10] for millet and [16] for finger millet.

Bulk density, True density and porosity

The bulk density, true density and porosity for *Kodo* millet determined at different moisture contents ranging from 8.19 to 12.71 per cent (db). The bulk density decreased from 0.67 to 0.62 g ml^{-1}linearly with increase in moisture content, but true density and porosity increases with increase in moisture content from 1.20 to 1.24 g ml^{-1} and from 43.99 to 50.27 per cent, respectively. Shown in (Table2) and (Fig 7)

$$B_d = -0.008\,M + 0.727 \quad (R^2 = 0.773) \quad \dots(19)$$

$$T_d = 0.006\,M + 1.159 \quad (R^2 = 0.543) \quad \dots(20)$$

$$\varepsilon = 1.077\,M + 37.14 \quad (R^2 = 0.705) \quad \dots(21)$$

Where, B_d = bulk density g/ml; T_d= True density g/ml; ε = Porosity; and

M = Moisture content % (db)

Similar decreasing trends in bulk density and variation in true density with increase in moisture content have been reported by [14], [16] and [10] for *Kodo* grain, gram and for millet respectively. The change in porosity of the *Kodo* grain with the increase in moisture content is Similar increasing trends with increase in moisture content have been reported [18] for wheat.

Angle of repose

The Angle of repose for *Kodo* determined at different moisture contents ranging from 8.19 to 12.71 per cent (db) increase with increase in moisture content. Shown in (Table2) and (Fig. 8).The following regression line was fitted to the data, which adequately (R^2=0.729) explains the relationship between the moisture content and angle of repose:

$$\theta = 0.0148M + 24.26 \quad (R^2 = 0.729) \quad \dots(22)$$

Where,θ = angle of repose of *Kodo*, ° and M = Moisture content, % (db)

Similar increasing trends with increase in moisture content have been reported by [14] for *Kodo* grain, [10] for millet, [18] for wheat and [19] for foxtail millet, little millet, *Kodo* millet, common millet, barnyard millet and finger millet.

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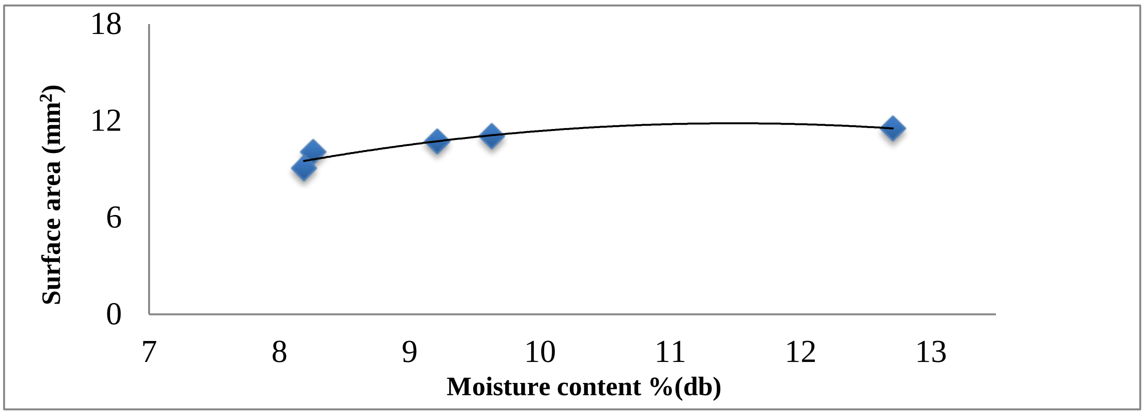

Fig.5: Effect of moisture content on Surface area of *Kodo* grains

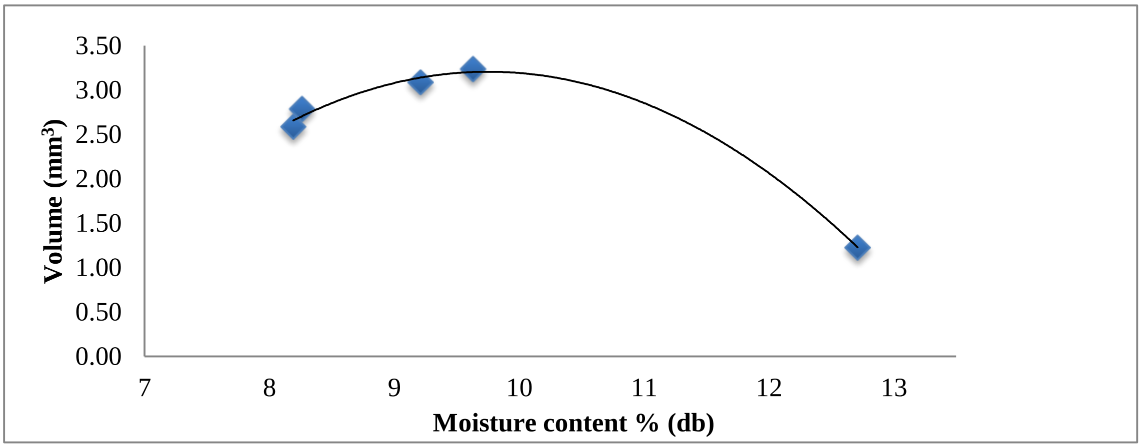

Fig.6: Effect of moisture content on Volume of *Kodo* grains

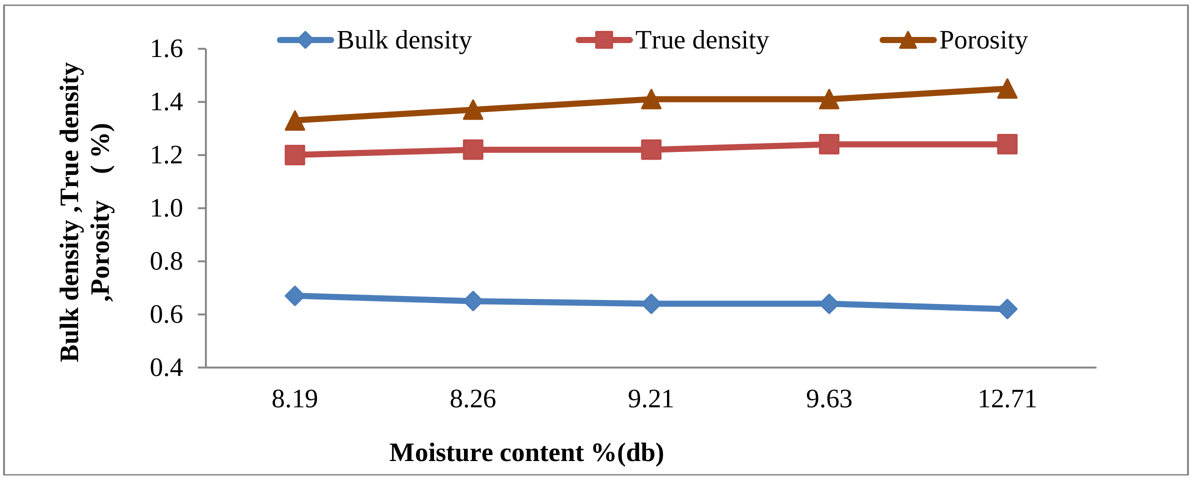

Fig.7: Effect of moisture content on Bulk, True density and Porosity of *Kodo* grains

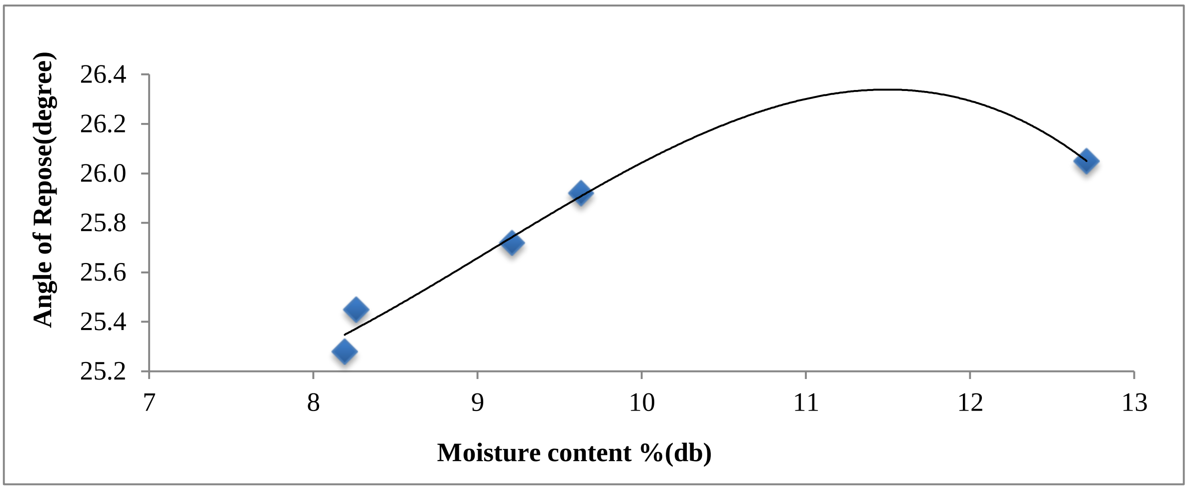

Fig. 8: Effect of moisture content on Angle of Repose of *Kodo* grains

IV.CONCLUSION

It was observed that the length width and thickness of *Kodo* increased with increasing moisture content. Also observed that with the increase moisture content the length-breath ratio of *Kodo* decreased. The size and sphericity of *Kodo* increased with the increase moisture content, Surface area and volume of *Kodo* grains increased with the increase in moisture content. The values of bulk density decrease but true density and porosity was increase with increase in moisture content. The Angle of repose was increase with increase the moisture content.

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