Moisture-dependent physical properties of cocoa (*Theobroma cacao*) pods

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ABSTRACT

Utilization of crop residues is of paramount importance to reduce the quantity of waste generated and aid conversion of waste to wealth. Literature is scarce on engineering properties of cocoa pod (physical, thermal, electrical, optical) which are needed for design of processing and handling machineries for the materials. Thus, the influence of moisture content on some physical properties of cocoa pod was investigated. The properties were determined in accordance with standard evaluation methods at moisture content levels 12.45, 24.37, 34.35, 38.37 and 44.5% db. The length, width, thickness, geometric mean diameter, sphericity and surface showed an inverse relationship with the moisture content of the cocoa pod, average values obtained (185.84- 185.9, 78.28-78.38, 78.24-78.39, 104.43-104.55 $x10^{-3}$m, 0.5619-0.5623 and 34326.48-34326.48 $x10^{-6}$m respectively) increases at moisture content decreased from 44.5 – 12. 45% db. The results indicated that the physical properties decreased with increase in moisture content. Regression models depicting relationship between moisture content and physical properties showed accuracy of the equations being suitable for engineers in design of efficient equipment and process for economical energy consumption.

Keywords: Physical properties, moisture content, cocoa pod.

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INTRODUCTION

Agricultural residues are remnants remaining in the field after harvest and processing of crops during food, feed and fiber production (BRFS, 2008). The production of agricultural residues and wastes occupies a substantial part of the Nigeria agricultural industries and constitutes over 70% of total residues generated in the cities; these wastes are mainly from grasses, field crops, animal husbandry, chaff from processed foods and crops. The competition between man and livestock for food such as cereals, pulses and oil seeds is partly responsible for the ever-increasing livestock feed costs. In developing countries, the production of these feed items is too low to meet demands, and as in all such situations, where demand exceeds supply, the cost of these items has continuously soared. Research efforts have therefore been directed towards finding alternative sources of nutrients for livestock, using materials that cannot be directly consumed by man. This approach may alleviate man-livestock competition and reduce livestock feed costs particularly for ruminants which can utilise fibrous crop residues and byproducts of cereals, pulses and oil seed processing.

Enormous quantities of these materials which are usually not eaten by man, are produced annually on the farm after crop harvesting and in the food processing industry. Many of these materials are currently being evaluated on a worldwide basis in order to determine their suitability as livestock feeds. Cocoa-pod produced after the removal of the cocoa beans from the fruit, is one such crop residue being evaluated in Nigeria as a potential feed for ruminants. The pod forms about 75 - 80% of the weight of the fruit, and from estimates of cocoa production in Nigeria, about 1 million tonnes of dried pod could be available annually on Nigerian cocoa plantations for feeding ruminants. Many by–products that are considered as wastes in Nigeria have great potentials as livestock feed ingredients if properly handled, processed and incorporated into rations. Some of such wastes are cocoa bean shell (CBS), cocoa pod husk (CPH), kola testa (KOT) and kola pod husk (KPH). Nigeria is one of the world largest producers of cocoa and kola and hence the by-products of these crops are abundantly wasted and constitute nuisance at farmstead and/or processing factory sites (Hamzat and Adeola, 2011). Cocoa tree pruning is normally left in the field as a kind of mulch while a small part may be used as domestic fuel. Cocoa pods are normally left in the field. No information is available on what is being done with wood from trees cut during re-planting. It may be assumed that a major part of this wood ends up as domestic or industrial fuel (FAO, 2017). A perusal of literature shows that there is no information on the engineering properties of crop residues like cocoa pods. The engineering properties include physical, thermal, mechanical, optical, electrical properties which are required by food processors, designers and engineers as guide in design of machine parts and components. Hence, the objective of this study was to investigate the influence of moisture content on the physical properties of cocoa pods.

MATERIALS AND METHODS

Sample Collection and Preparation

Fresh samples of cocoa pods were obtained from Oyo State Ministry of Agriculture, Oyo State, Nigeria. The residues were manually cleaned and sorted to remove foreign or dissimilar materials.

Moisture Content

Determined in accordance with ASAE Standard S358.2 (1983). Initial moisture content (*MC*) of the samples was determined using oven-drying method; the pods were dried at 105ºC for 24 hours (AOAC, 1990). Samples of cocoa pods were conditioned to five different moisture levels through dehydration and rehydration. The moisture content of the sample in percent dry basis was calculated using the following equation:

$$Ms = \frac{100\,(W_i - W_f)}{W_f}$$

Where: *Ms* is the moisture content (% dry basis), *Wi* is the initial mass of seeds before oven drying (in grams) and *Wf* is the final mass of seeds after oven drying (in grams).

Axial Dimension (Length, Width and Thickness)

Four samples from each moisture content category were randomly selected; a digital Vernier Caliper and Neil Micrometer Screw Gauge (Tork Craft Company, VER/ME12150, Quanzhou, China, $\pm$0.01) was used for measuring the length (a), width (b) and the thickness (c) as major, minor and intermediate diameters respectively. Readings were taken and recorded.

Geometric Mean Diameter

The geometric mean diameters of the samples were calculated using the mathematical expression cited by Mohsenin (1970):

$$Gm = (L.W.T)^{\frac{1}{3}}$$

Where: Gm is the geometric mean diameter (mm), L is the Length (mm), W is the width (mm) and T is the thickness (mm)

Sphericity

Determined using the practical 3-dimensional expression; the higher the sphericity value of a material, the closer its shape to a sphere, this property is useful in the design of hopper and dehulling equipment for agricultural products, it determines the tendency of a material to roll when placed on a particular orientation. The degree of sphericity of the pods was calculated using the Equation described by Mohsenin (1970, 1986) and applied by Ogunlade *et al.,* (2016).

$$\text{Sphericity (S)} = \frac{(L.W.T)^{1/3}}{L} = \frac{Gm}{L}$$

Where: S is the Sphericity in decimal, L is the length (mm), W is the width (mm) and T is the thickness (mm), Gm is the Geometric Mean diameter (mm).

Surface Area

The surface area of the samples was calculated using the mathematical expression given by McCabe *et al* (1986), Mohsenin (1986), Orji (2001), Olukunle and Atere (2001), Asoiro and Anthony (2011), Ajav and Ogunlade (2014).

$$S = \pi Gm^2$$

Where: S is the surface area, Gm is the Geometric Mean diameter (mm)

Volume and True Density

The volume of the pod of a known weight was determined by putting the sample in a cuboid of a known volume; the cuboid was filled with the pods. The pods were removed while the volume occupied was measured in volumetric cylinder. The difference in the volume was calculated as the volume of the samples. The experiment was replicated three times and density was calculated using the ratio of the weight and the volume of the samples at different moisture level as reported by Desphande *et al.* (1992) and Aremu *et al.* (2014)

$$Vs = \mathrm{Vc} - \mathrm{Vg}$$

Where: V_s is the Volume of the sample (cm^3), V_c is the Volume of cuboid (cm^3) and V_g is the Volume occupied by the pods (cm^3)

Bulk Density

The bulk density of the selected samples was determined using the method described by Singh and Goswami (1996) and Ogunlade *et al.* (2016) in which a 250ml volumetric cylinder was filled with samples of Cocoa pod; the weight of the samples was weighed. Bulk density was calculated using the ratio of the weight and the volume of the cylinder.

RESULTS

The result obtained from the measurement of the geometric/axial dimension of cocoa pods as affected by moisture content is presented in Table 1. The influence of moisture content on True and bulk density of the cocoa pods is also presented in Figures 1 and 2 respectively.

Table 1: Axial Dimensions of Cocoa Pods

Moisture content (%db)	Length ($x10^{-3}$m)	Width ($x10^{-3}$m)	Thickness ($x10^{-3}$m)	Geometric mean diameter ($x10^{-3}$m)	Surface area ($x10^{-6}m^2$)	Sphericity
12.45	185.9	78.38	78.34	104.53	34326.48	0.5623
24.37	185.89	78.36	78.39	104.55	34313.54	0.5622
34.35	185.87	78.32	78.31	104.47	34286.28	0.5620
38.37	185.86	78.29	78.21	104.44	34267.59	0.5619
44.50	185.84	78.28	78.24	104.43	34261.03	0.5619

Linear regressions were obtained depicting the relationship between true and bulk density of the cocoa pods and their relative moisture content as presented below:

$\rho = 0.377 - 0.003MC_{(\%, d.b)}$ $\quad r = 0.981$

$\rho_b = 0.521 - 0.003MC_{(\%, d.b)}$ $\quad r = 0.891$

Where ρ is the true density of the pods (g/cm^3) and ρ_b is the bulk density of the pods (g/cm^3).

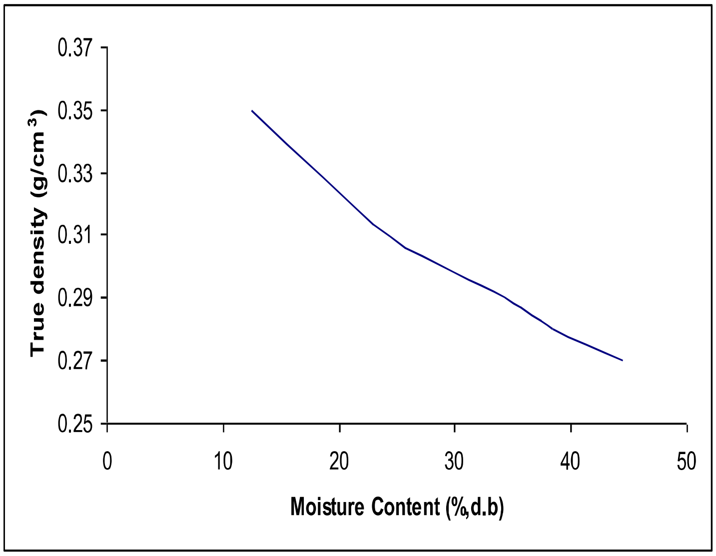

Figure 1: Influence of moisture content on True density of cocoa pods

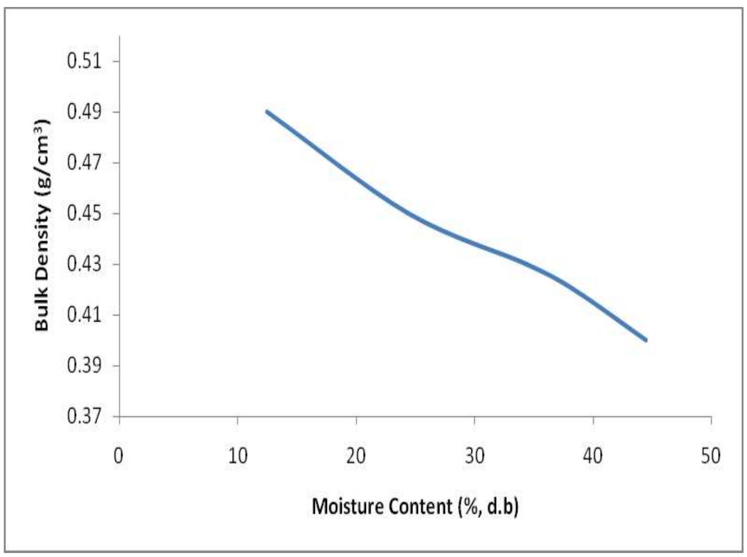

Figure 2: Effect of moisture content on bulk density of cocoa pod

DISCUSSION

An inverse relation was observed in the relationship between moisture content and the axial dimensions; the length, width, thickness, geometric mean diameter, sphericity and surface showed an inverse relationship with the moisture content of the cocoa pods, average values obtained (185.84- 185.9, 78.28-78.38, 78.24-78.39, 104.43-104.55 x10^{-3}m, 0.5619-0.5623 and 34326.48-34326.48 x10^{-6}m respectively) increases at moisture content decreased from 44.5 – 12. 45% db. The sphericity values obtained for the cocoa pod showed that cocoa pod is not a perfect spherical body which makes its rolling difficult. Similar trend was reported for parchment coffee bean by Perez-Alegria *et al* (2001) in which the sphericity decreased with increase moisture content.

The true and bulk densities of the cocoa pod were observed to be a linear function of moisture content. The true and bulk density decreased with increase in moisture content from 0.35 to 0.27g/cm^3 and 0.49 to 0.40 g/cm^3 for the cocoa pods. Irtwange and Igbeka (2002) and Visranathan *et al* (1996) reported similar decreased with moisture content for two African yam bean (TSs 137 and TSs 138) and Neem nut; Desphande *et al* (1993) obtained similar trends with moisture content for soybean.

CONCLUSION

The effect of moisture content on some physical properties of cocoa pods was investigated, it was observed that an increase in the moisture content led to decrease in true and bulk densities of the cocoa pods. The result showed that there is a strong linear correlation between density (true and bulk) and moisture content of the samples. The true and bulk densities of the cocoa pod were linear functions of moisture content. Also, the average values obtained for the sphericity, mean diameter and surface area were dependent on moisture content of the cocoa pod.

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