THE EFFECTS OF REWETTING AND DRYING ON SELECTED PHYSICAL PROPERTIES OF 'OBATANPA' MAIZE VARIETY

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ABSTRACT

The physical properties used to analyse forces in storage structures have been evaluated as a function of grain moisture content varying from 12% to 25% (w.b) and 12.4 % to 24 % (w.b) for rewetting and drying respectively for the 'Obatanpa' maize variety. In this moisture range studied, the bulk density decreased non-linearly with increasing moisture content within a range of 789.296 kg/m^3 to 674.28 kg/m^3 and 766.97kg/m^3 to 660.20kg/m^3 for rewetting and drying of the grain sample respectively. The angle of repose increased linearly from 22.19° to 29.07° and 22.48° to 29.40° for rewetting and drying respectively. The coefficient of static friction on various surfaces increased non-linearly with moisture content. The plywood offered the maximum friction followed by mild steel and then rubber. The percentage errors for the properties determined varied from 0.02 to 4.9% for both drying and rewetting of the grain samples, which was within acceptable limits.

Keywords: Obatanpa maize, Bulk density, Angle of repose, coefficient of static friction.

1. INTRODUCTION

Maize (*Zea mays*) is a member of the grass family, Gramineae, to which all the major cereals belong. Cultivated maize survives without human husbandry. It has the highest potential for grain yield amongst all the cereals. It is the leading starchy-staple by a large margin. It does best on soils of neutral acid reaction of pH 7.

The types of grains recognized are pod corn, flint maize, dent maize, sweet corn, floury maize, popcorn and waxy maize. Maize grain is palatable, nutritious and rich in energy producing carbohydrates (starch) and fats. It is high in fat than rice or wheat (94% versus 92%). Maize is low in calcium, fairly high in phosphorous, and exceptionally rich in vitamin A. Maize grain has generally good storage properties. Freshly harvested maize contains about 30% moisture content and must be dried first, preferably to between 12 – 14% moisture content before storage. Maize is one of the crops cultivated by majority of farmers in Ghana. This is due to the fact that, it is relatively easy to cultivate, has a large yield, short maturating period and can be stored for a long time.

Maize is used in more ways than any other cereal. It is used for human food, feed for livestock and for industrial purposes. Every part of the plant has economic value. The grain, leaves, stalk, tassel and even the cob are used to produce food and non-food products (Watson, 1988). The physical properties of maize, like those of other grains and seeds are essential for the design of equipment for handling, harvesting, processing and storing the grains. The physical properties of maize related to forces in storage structures include bulk density, angle of repose and static coefficient of friction (Boumans, 1985). There are new varieties of maize currently on the Ghanaian market such as 'Okomasa', 'Dobidi', 'Dorke', 'Mamaba' and 'Obatanpa' released by the Crop Research Institute of Ghana whose physical properties needed in the analysis of loads on storage structures are not well documented. This project therefore seeks to bring out these physical properties to help engineers in the design of storage structures. In storage maize samples could absorb moisture as condensation on the walls of the structures take place especially for metal wall and loss of moisture is also expected when aeration takes place. The values obtained for the properties under consideration could depend on the method used in conditioning the samples. This study is therefore designed to evaluate and compare the effects of drying and rewetting on the physical properties of 'Obatanpa' maize variety which are utilised in the analysis of silo loads.

The objectives of this study was to determine the variation of bulk density, filling angle of repose, static coefficient of friction on surfaces of plywood, mild steel and rubber when the samples are rewetted and then dried.

NOTATION

MC - Moisture content (%w.b)
θ – Angle of repose (°)
μ_P - Static coefficient of friction on plywood
h - height of heap (mm)
μ_m - Static coefficient of friction on mild steel
R - radius of heap (mm)
μ_R - Static coefficient of friction on rubber
ρ_B - Bulk density (kg/m^3) w.b Wet basis
R^2 - Coefficient of determination

2. MATERIALS AND METHODS

2.1 Sample Preparation

Grain samples used were certified seeds from Grains Development Board, Kumasi, Ghana. Calculated amounts of distilled water were added to raised the moisture contents of grain samples to the desired levels. The desired moisture content for the higher values was obtained by adding a calculated amount of distilled water to

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the samples using the relation:

$$Qw = \frac{Ms(m_f - m_i)}{100 - m_f} \quad 1$$

where Q_w = Quantity of water to be added (kg)
m_i = initial moisture content
m_f = desired final moisture content
Ms = Mass of Sample to be conditioned (kg)

The seeds were thoroughly mixed and then stored in an airtight polythene bags for 3 days in a refrigerator to allow the moisture to diffuse through uniformly. Similar approaches have been used by Suthar and Das (1996), Aviara et al.(1999), Deshpande et al. (1993) and Singh and Goswami (1996) for other grains and seeds.
The sun-drying method was adopted in this study for lower moisture contents. Moisture contents were determined by the oven dry method and expressed on wet basis.

2.2 Bulk Density

Bulk density, which is the mass of a sample of grain divided by the volume occupied by the grain and intergranular space, was measured using a previously weighed measuring cylinder of 530ml volume filled with the grain and levelled with a piece of string. The weight of the grains and cylinder was taken using an electronic balance. The ratio of the mass of grains to the volume of grains was then taken as the bulk density. Several researchers including Baryeh (2001), Deshpande et al. (1993), Jain and Bal (1997), Sharma et al. (1985) and Suthar and Das (1996) have employed a similar method for other grains and seeds.

2.3 Filling Angle of Repose

The filling angle of repose was determined by allowing grains to fall from a height of 120cm onto a circular wooden plate of 20cm diameter forming a natural heap (Boumans, 1985). The height (h) and the radius(r) of the heap was measured and used to determine the angle of repose as:

$$\theta = \tan^{-1}\left(\frac{h}{r}\right) \quad 2$$

4 Coefficient of Static Friction

The coefficient of static friction was determined using three surfaces, namely plywood, mild steel and rubber. The material surfaces were hinged at one end to a tilting table and free at the other end with a support made of a bolt and nut arrangement. A circular PVC pipe opened at both ends with a height of 8cm and diameter 10cm was placed on the sliding surface. The PVC pipe was filled with grains and then lifted slightly so that it was not resting on the surface. The sliding surface was tilted slowly by a manually driven screw and nut arrangement until the operator detected movement of the whole grain mass together with the PVC. The coefficient of friction was the tangent of the slope angle that the sliding surface made with the horizontal (Figure 1).

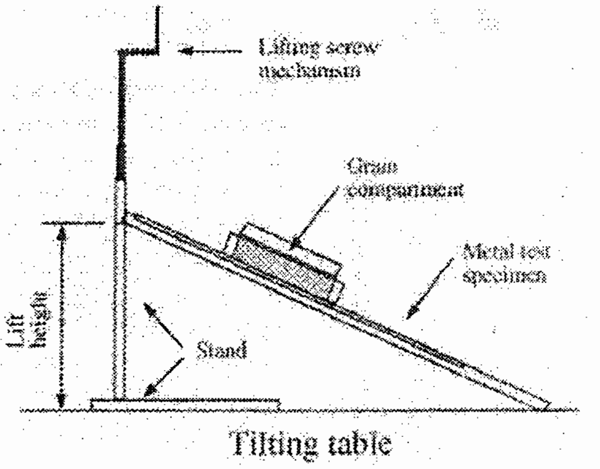

Figure 1. Coefficient of friction measuring apparatus

All the measurements for the properties studied were replicated five times and the averages taken.

3. RESULTS AND DISCUSSIONS

3.1 Bulk Density

The values of bulk density for different moisture levels varied from 674.28 to 789.30 kg/m^3 for rewetting and 660.20 to 766.97 kg/m^3 for sun drying. A plot of experimentally obtained values of bulk density against moisture content in fig. 2 indicates a decrease in bulk density with an increase in moisture content in the specific moisture range for both drying and rewetting of the grains. The bulk density was slightly higher under rewetting than drying. Likewise, it shows a non-linear variation with moisture content. This indicates that the method for the determination of bulk density should always be indicated.

The decreasing trend in bulk density was reported by Deshpande and Bal, (1993) for soybean in the moisture range of 7.4 to 20% (w.b). Baryeh (2001), who investigated into the physical properties of bambara groundnuts also reported a similar trend as the moisture content increased up to 25%, beyond which bulk density did not change appreciably. The bulk density of pumpkin seeds (Joshi et al., 1993), coffee (Chandrasekar and Viswanathan, 1999) increased as moisture content increased. These variations could be due to variation in mass and volume increase characteristics of different crops as moisture content increases. Based on the regression analyses which was in relation to the Orthogonal polynomials, the variations of bulk density for 'obatanpa' in the moisture range studied for other moisture content values could be found with the following predictive equations:

Drying: $r_b = 0.26MC^2 - 18.49MC + 956.57$ $R^2 = 0.99$
Rewetting: $r_b = 0.02MC^2 - 9.33MC + 897.26$ $R^2 = 0.96$

3.4 Filling angle of Repose

The variation of filling angle of repose with moisture content is plotted in Figure 3.

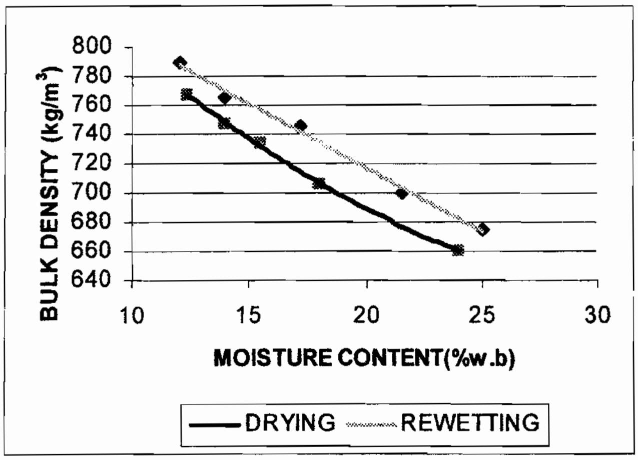

Figure 2: Effects of drying and rewetting on bulk density at different moisture contents.

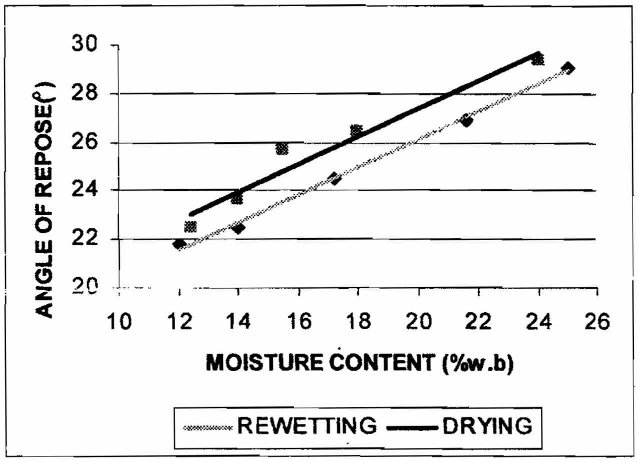

Figure 3. Variation of filling angle of repose with moisture content for drying and rewetting.

Between moisture content of 12 and 25%w.b, the filling angle of repose increased when the grains were rewetted, with values increasing from 22.196° to 29.07°. For drying the angle of repose increased from 22.48° to 29.40° in the moisture content range of 12.4 and 24%w.b. The angle of repose under both conditions increased linear with moisture content as shown in fig 3. The values were however slightly higher for drying conditions than rewetting. This difference could be due to differences in the surface roughness of the grains as they get wet, which affect their ability to form a heap.

Result obtained is similar to that found for bambara groundnut (Baryeh, 2001) and pumpkin seeds (Joshi et al, 1993).
The relationship between filling angle of repose and moisture content for both drying and rewetting could be analysed for other moisture content other than what was studied with the following predictive equations:

Drying: $q = 0.58MC + 15.82$ $R^2 = 0.96$
Rewetting: $q = 0.57MC + 14.76$ $R^2 = 0.99$

3.5 Static Coefficient of Friction on Plywood, Mild Steel and Rubber.

The static coefficient of friction as depicted in Figure 4 increased non-linearly with increasing moisture content from 0.302 to 0.490, 0.274 to 0.438 and 0.253 to 0.490 for plywood, mild steel and rubber respectively for rewetting in the moisture range of 12 to 25% wb. For drying conditions (Figure 5) there was also a non-linear increase with increasing moisture content from 12.4 to 24% wb on all the three surfaces, for plywood from 0.263 to 0.420, mild steel from 0.242 to 0.40 and rubber from 0.247 to 0.302 respectively.

Observations from Figures 4 and 5 show that, plywood offered the maximum friction followed by mild steel and rubber offering the least friction during rewetting and drying respectively. This trend could be due to the slippery nature of rubber compared to plywood and the fact that mild steel had a smoother surface than plywood

The increasing friction coefficient at high moisture contents may be as a result of the presence of more water in the maize, which offered a greater cohesive force on the surface of contact. The variation can be expressed mathematically as follows:

Drying: $\mu_p = -0.0005MC^2 + 0.0242MC + 0.0265$ $R^2=0.93$

Rewetting: $\mu_p = 0.001MC^2 - 0.0254MC + 0.4124 R^2=0.98$

Drying: $\mu_m = -0.0009MC^2 + 0.047MC - 0.2045$ $R^2= 0.99$

Rewetting: $\mu_m = 0.0009MC^2 - 0.0186MC + 0.3683$ $R^2=0.97$

Drying: $\mu_r = 0.0011MC^2 - 0.0274MC + 0.4666$ $R^2= 0.99$

Rewetting: $\mu_r = 0.0009MC^2 - 0.0186MC - 0.3683$ $R^2=0.96$

The effects of moisture content on the physical properties of maize studied are reflected in the shrinkage and swelling characteristics inherent in the processes of both drying and rewetting respectively.

4. CONCLUSIONS

The investigations of various physical properties of obatanpa maize variety revealed the following:

1. All the physical properties of maize studied in this work varied with moisture content.
2. The entire results provide basic data for analyses of forces in maize storage structures.
3. The bulk density of decreased non-linearly with increase in moisture content in the range, 12 to 25% w.b and 12.4 to 24% w.b for rewetting and drying respectively.
4. The angle of repose increased linearly from 22.19° to 29.07° for rewetting in the grain moisture content range of 12 to
5. The static coefficient of friction for rewetting increased non-linearly with increasing moisture content from 12 to 25% w.b on all the three surfaces namely plywood (0.302 to 0.490), mild steel (0.274 to 0.438) and rubber (0.253 to 0.490) for rewetting. There was also a non-linear increase with increasing

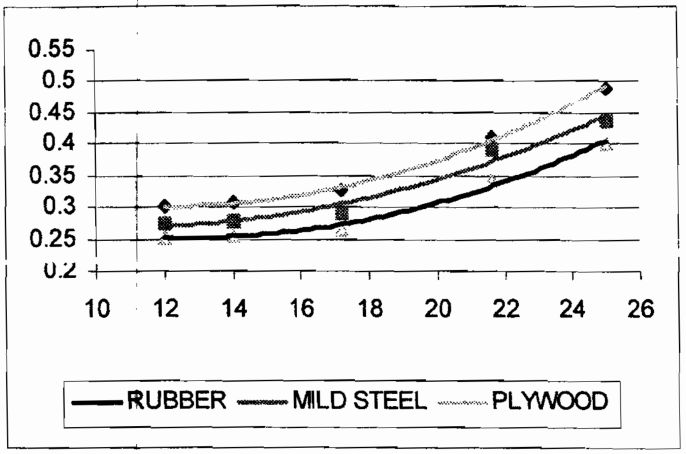

Fig 4. Effect of moisture content on the coefficient of static friction for rewetting.

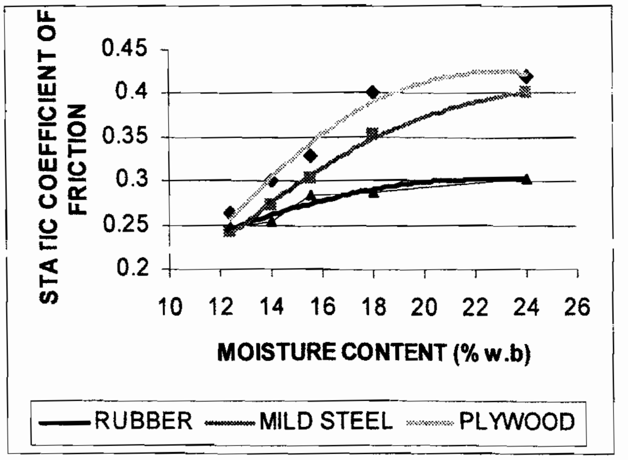

Fig 5. Effect of moisture content on the coefficient of static friction for drying.

moisture content from 12.4 to24% wb on all the three surfaces, plywood (0.26 to 0.42), mild steel (0.24 to 0.40) and rubber (0.25 to 0.30). For both conditions, plywood offered the maximum friction followed by mild steel and then rubber offered the least friction.

6. The percentage errors for the properties determined varied from 0.02 to 4.9% for both drying and rewetting of the grain samples, which was within acceptable limits.

REFERENCE

Aviara, N. A., Gwandzang, M. I., Hague, M. A. (1999). Physical Properties of Guna Seeds. Journal of Agricultural Engineering Research, 73, 105-111.

Baryeh, E. A. (2001) Physical properties of Bambara groundnut. Journal of Food Engineering, 47 (2001) 321-326.

Bouman, G., (1985). Grain Handling and Storage (Developments in Agricultural Engineering 4). Elsevier Science Publishers, Amsterdam.

Deshpande, S. D., Bal, S. and Ojha, T. P. (1993). Physical properties of soybean, Journal of Agricultural Engineering Research 56, 89-98.

Faborode, M.O and Omotande, S.A, (1993) Effect of rewetting and drying on some physical properties of cocoa beans. Journal of Agriculture, Science and Technology., 3(2);182-189.

Jain, R. K. and Bal, S. (1997). Physical properties of pearl millet. Journal of Agricultural Engineering Research, 66, 85-91.

Joshie, D. C., Das, S. K. and Mukherjee, R. K. (1993). Physical properties of pumpkin seeds, Journal of Agricultural Engineering Research 54,219-229.

Kukelko, D.A, Jayas, D.S, White, N.D.G and Britton, M.G. (1988) Physical properties of canola (rapeseed), Canadian Agricultural Engineering, 30: 61-64.

Muir, W.E and Sinha, R.N (1988). Physical properties of cereal and oilseed cultivators grown in western Canada, Canadian Agricultural Engineering, 30 (1), 51-55.

Sharma, S.K, Dubey, R.K and Teckchandani, C. K. (1995). Engineering properties of black gram, soybean and green gram. Preceedings of the Indian Society of Agricultural Engineers, 3, 118-185.

Singh, K. K., & Goswani, T. K. (1996). Physical properties of Cumin Seed. Journal of Agricultural Engineering Research, 64, 93-98.

Suthar, S. H., & Das, S. K. (1996). Physical Properties of Karingda [*Citrullus lanatus* (Thumb) Mansf] Seeds. Journal of Agricultural Engineering Research, 65, 15-22.

Versavel, P.A. and W.E. Muir. 1988. Drying of rewetted wheat-spikes. Canadian Agricultural Engineering. 30(1):57-60.