Effects of Moisture Content on Selected Physical Properties of Two Varieties of Cowpea

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Received: June 2002 Accepted: October 2005

Resumé

Bart-Plange, A., Dzisi, K. A., & Darko, J. O. *Les Effets de teneur en humidité sur les propriétés physiques choisies de deux variétés de niébé.* Les propriétés physiques de niébé sont nécessaires pour le dessin et la construction des équipements et des structures pour le maniement, la transportation, le traitement et le stockage des haricots et dans l'estimation de la qualité du produit. Les propriétés physiques de deux nouvelles variétés ("Asetenapa" et "Adom") de niébé produites au Ghana étaient évaluées comme une fonction de teneur en humidité d'haricot variant de 10% à 26% (wb). Dans le domaine de l' humidité étudié, le 1000 masse d'haricot a augmenté linéairement de 125.75 à 143.85 g et 147.16 à 180.14g quand l'humidité a augmenté de 12.19 à 25.40% et 11.55 à 24.36% pour "Adom" et "Asetenapa" respectivement. Le gros de la densité a diminué linéairement de 792.15 à 746.75 kg m^{-3} et 829.92 à 770.99 kg m^{-3} quand l'humidité a augumenté de 12.19 à 25.40% pour "Adom" et 11.55 à 24.36% pour "Asetenapa". L'angle de remplissage de répos a varié de 27.47 à 33.18% pour "Asetenapa" dans le rang d'humidité de 11.55 à 24.36% et de 26.56 à 32.29% pour "Adom" quand l' humidité a augmenté de 12.19 à 25.40%. Le coefficient statique de friction a augmenté linéairement de 0.273 à 0.331, 0.317 à 0.425 et 0.325 à 0.443 pour caoutchouc, le contre plaqué et l'acier léger respectivement pour "Asetenapa". Pour "Adom" une augmentation linéaire en coefficient statique de friction de 0.273 à 0.331, 0.317 à 0.425 et 0.325 à 0.443 pour le caoutchouc, le contre plaqué et l'acier léger respectivement était observé. L'effet d'humidité sur les propriétés étudiées pour le deux variétés étaient trouvés d'être bien considérable ($P < 0.01$) pour 1000 masse en haricot, le gros de la densité et l' angle de répos mais considérable ($P < 0.05$) pour coefficient de la friction statique. Les équations prédictives avec R^2 rangeant énormément de 0.90 à 0.99 pour les propriétés étudiées ont été développés.

Mots clés: Niébé, propriétés physiques, le gros de la densité, angle de répos, coefficient de la friction statique.

Abstract

The physical properties of cowpea are necessary for the design and construction of equipment and structures for handling, transportation, processing and storage of the beans and in the assessment of product quality. The physical properties of two new varieties

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("Asetenapa" and "Adom") of cowpea produced in Ghana were evaluated as a function of bean moisture content varying from 10% to 26% (wb). In the moisture range studied the 1000-bean mass increased linearly from 125.75 to 143.85 g and 147.16 to 180.14 g when moisture increased from 12.19 to 25.40% and 11.55 to 24.36% for "Adom" and "Asetenapa", respectively. The bulk density decreased linearly from 792.15 to 746.75 kg m^{-3} and 829.92 to 770.99 kg m^{-3} when moisture increased from 12.19 to 25.40% for "Adom" and 11.55 to 24.36% for "Asetenapa". The filling angle of repose varied from 27.47 to 33.18° for "Asetenapa" in the moisture range of 11.55 to 24.36% and from 26.56 to 32.29° for "Adom" when moisture increased from 12.19 to 25.40%. The static coefficient of friction increased linearly from 0.287 to 0.335, 0.329 to 0.456 and 0.337 to 0.467 for rubber, plywood and mild steel, respectively for "Asetenapa". For "Adom", a linear increase in static coefficient of friction from 0.273 to 0.331, 0.317 to 0.425 and 0.325 to 0.443 for rubber, plywood and mild steel, respectively was observed. Effect of moisture on the properties studied for the two varieties were found to be highly significant ($p < 0.01$) for 1000-bean mass, bulk density and angle of repose but significant ($p < 0.05$) for coefficient of static friction. Predictive equations with R^2 ranging mostly from 0.90 to 0.99 for the properties studied have been developed.

Keywords: Cowpea, physical properties, bulk density, angle of repose, coefficient of static friction.

Introduction

Cowpea (*Vigna unguiculata*), which is known in some places as southern pea or black-eyed pea, is cultivated in 16 African countries currently (NGICA, 2004, Langyintuo, 2005). In tropical Africa cowpea is a popular food bean used to supplement animal protein, vitamins, minerals and essential amino acids (Giami, 2005; Fery, 2002; IITA, 2004; Dovlo *et al.*, 1976; Langyintuo, 2004; Ng and Marechal, 1985).

They are used in over 50 different dishes in both whole grain and milled form either boiled, fried or steamed (Dovlo, 1985). Several varieties have been developed to withstand drought, stress, disease and pests and others have also been developed for high yields, early maturity and improved nutritional quality (Langyintuo, 2005; Ogbuinya, 1997; Singh and Eaglefield, 2000; Edde, 2001; Ladeinde, 1977). In Ghana eight cowpea varieties including the most common ones: "Bengpla", "Soronko", "Asontem", "Amantin", "Ayiyi", "Adom" and "Asetenapa" have been released between 1979 and 1992 under Ghana/CIDA Grains Development Project (CRI, 2005; AFAMIN Ghana, 2005).

Considering the importance of cowpea, both economically and nutritionally, efforts must be directed to improve its storage and processing technologies. Among the engineering properties, the physical properties of grains and legumes are more important in the agricultural process engineering for the post harvest operations (Vaishnava *et al.,* 2000). The relative percentage of moisture in food materials is dynamic and it influences the physical properties and product quality of nearly all food materials at all stages of processing and final product existence as well (Werolowshi, 2003).

The moisture-dependent physical properties of the beans such as bulk density, angle of repose and coefficient of static friction may affect the adjustment and the performance of equipment for processing, storage and handling. The optimum performance of a processing equipment may be attained within a certain moisture range and therefore knowledge about these physical properties of the beans and their variation with moisture is very important in the construction of storage, handling and processing equipment (Baryeh, 2001). The angle of repose, which is influenced by product type and characteristic, is a useful indicator of a product's ability to flow. In general, the lower the angle of repose, the easier the product flows. The coefficient of static and sliding friction, which depend on the size and shape characteristics of the product and the roughness or smoothness of the walls can be used to determine the type of flow in a silo during discharge of a product (Boumans, 1992). The angle of repose and the frictional resistance on metal, concrete, wood and others will influence the design of silo geometry, hopper shape, outlet opening and form.

The physical properties, which vary with moisture such as 1000-bean mass, bulk density, angle of repose and coefficient of static friction have been investigated for pigeon pea, pumpkin seed, soybean, sunflower seeds, guna seeds, cumin seeds, coffee beans, karingda seeds, neem seeds and bambara groundnuts (Shepherd and Bhardwaj, 1986; Joshi *et al.*, 1993; Deshpande *et al.*, 1990; Gupta and Das, 1996; Aviara *et al.*, 1999; Singh and Goswami, 1996; Chandrasekar and Viswanathan, 1999; Suthar and Das, 1996; Viswanathan *et al.*, 1996; Baryeh, 2001).

Available work done on cowpea concentrated on the improvement of disease and pest resistance, early maturity and high yields. Information on the physical properties of the Ghanaian varieties namely "Bengpla", "Soronko", "Asontem", "Amantin", "Ayiyi", "Adom" and "Asetenapa" and their moisture dependence is scarce.

The study was therefore designed to examine the 1000-bean mass, bulk density, angle of repose and coefficient of static friction for the "Asetenapa" and "Adom" varieties in the moisture content range of 10 to 26% as most post-harvest processing operations are performed in this range.

Materials and methods

Sample preparation

Two cowpea varieties (Asetenapa and Adom) were obtained from the warehouse of Crops Research Institute at Fumesua, Kumasi in the Ashanti Region of Ghana during the 2001/2002 major cowpea harvesting season. These varieties had been manually cleaned from all foreign materials such as dirt, broken beans, husk, pests and weeds at the farm level during the process of drying and were, therefore, ready for dissemination to farmers for production and consumption.

The initial moisture content of the Asetenapa and Adom varieties, which was estimated by the standard oven method were 11.55% and 12.19% (wb) respectively (Food storage manual, 1995). The beans were then conditioned for each variety to three other levels of moisture content in the range of 11-26% (wb) since most post-harvest operations are carried out in this range. The desired moisture content for the higher values was obtained by adding a calculated amount of distilled water to the samples using the relation:

$$Q_w = \frac{M_s(m_f - m_i)}{100 - m_f}$$

where Q_w = Quantity of water to be added (kg)

m_i = initial moisture content

m_f = desired final moisture content

M_s = Mass of Sample to be conditioned (kg).

The prepared samples were sealed in airtight polythene bags and kept in a refrigerator at 5°C for one week to allow the moisture to diffuse uniformly into the beans. Before using the beans polythene bags were selected randomly from the refrigerator and allowed to warm to room temperature (Baryeh, 2001; Deshpande *et al.*, 1993).

After conditioning, 1000-bean mass, bulk density, angle of repose and static coefficient were determined for four replicates and the mean values calculated for four levels of moisture content.

1000-bean weight determination

The 1000-bean weight was obtained by randomly picking 1000 beans from each variety and weighing them on an electronic balance to 0.01g accuracy.

Bulk density determination

The bulk densities of the two varieties were determined using a test procedure used by several researchers (Baryeh, 2001; Jain and Bal, 1997; Suthar and Das, 1996 and Deshpande *et al.*, 1993) for other grains and seeds. A 940ml size container was filled with the beans from a height of 15cm at a constant rate. The top of the container was levelled and no additional manual compaction was done. The bulk density was calculated as the ratio of the mass to the volume of the beans.

Determination of filling angle of repose

The filling angle of repose (θ) was obtained by the method described by Boumans (1992). The beans were allowed to fall onto a mounted circular plate of diameter 20cm from a falling height of 15cm to form a natural heap. The height of the heap was measured and the angle of repose (θ) was calculated as follows:

$\theta = \tan^{-1}(h/r)$, where h is the height of the heap (cm) and r is the radius of the plate (cm).

Static coefficient of friction determination

The coefficient of static friction (μ) for the beans was determined for three structural surfaces namely plywood, mild steel and rubber. A poly-vinyl chloride cylindrical pipe of 10cm diameter and 5cm height was filled with the sample and placed on an adjustable tilting friction test surface. The cylinder was raised slightly to avoid contact between it and the friction surface. The tilting surface with the cylinder resting on it was raised gradually with a screw device until the cylinder just started to slide down and the angle of tilt (γ) was recorded as the angle of static friction between the beans and the friction surface. The coefficient of static friction (μ) was computed from the relation: $\mu = \tan\gamma$.

Data analyses

The results obtained were analysed by means of the randomized complete block design for single factor experimental design. Statistical analysis using the F-test by Gomez and Gomez (1984) was used for the analysis of variance to determine significant differences between moisture variation and the properties studied.

Results and Discussion

1000-bean mass

Fig. 1 shows the variation of the 1000-bean mass with grain moisture content. The 1000-bean mass increased linearly for both varieties from 147.16 to 180.14g and 125.75 to 143.85g from moisture content of 11 to 26% for Asetenapa and Adom. The relationships can be represented by the following equations:

M_{1000} (Asetenapa) = 2.537M + 118.43, with a correlation coefficient, R^2, of 0.99 and M_{1000} (Adom) = 1.517M + 106.9, with a correlation coefficient, R^2, of 0.93. The linear increase in weight resulted from the moisture addition to the beans. However, it was found out that the 1000-bean mass of the Asetenapa variety was greater than that of Adom at any particular moisture content which indicated that the Asetenapa beans were heavier than the Adom. Moisture effects affected the values and this was highly significant ($P<0.01$).

Research on cumin seeds, soybeans, coffee, guna seeds and bambara

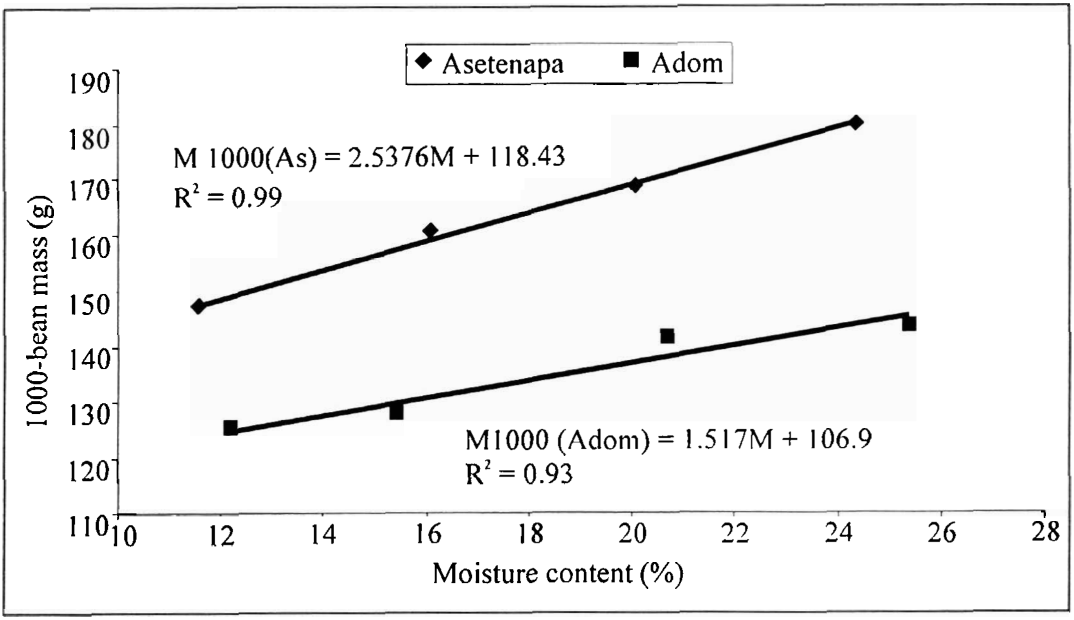

Fig. 1. 1000-bean mass against bean moisture content.

groundnuts by Singh and Goswami (1996); Deshpande *et al.* (1993); Chandrasekar and Viswanathan (1999); Aviara *et al.* (1999) and Baryeh (2001) show a similar linear relation for the 1000-bean mass.

Bulk density

The bulk densities obtained from 5 replications of each moisture content for the two varieties are shown in Fig. 2. The value of the bulk density decreased exponentially from 829.92 to 770.99 kgm^{-3} in the moisture content range of 11.55-24.36% for Asetenapa and from 792.51-746.75 kgm^{-3} in the moisture content range of 12.19-24.4% for Adom. The bulk density of Asetenapa was found to be greater than that of Adom at all moisture contents studied. Moisture effects were found to be highly significant ($p<0.01$).

The non-linear relationships with moisture content exhibited by the bulk densities may be given by the expression ρb (Asetenapa) $=1052.3M^{-0.098}$, with a correlation coefficient, R^2, of 0.99 and ρb (Adom) $= 973.46M^{-0.0828}$, with a correlation coefficient, R^2, of 0.99.

The bulk density of cumin seeds (Singh *et al.*, 1996), soybean (Deshpande *et al.*, 1990), sunflower seeds (Gupta & Das, 1997), guna seeds (Aviara *et al.*, 1999) and bambara groundnut (Baryeh, 2001) decreased as moisture content increased while an increasing linear relationship was found for coffee (Chandrasekar & Viswanathan, 1999), pumpkin seeds

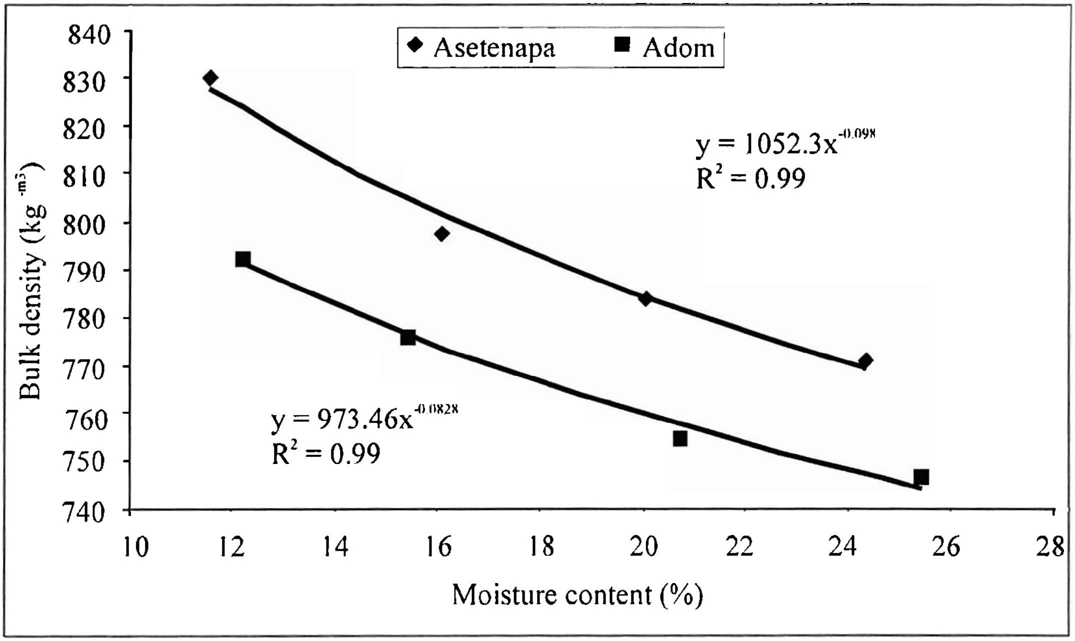

Fig. 2 Bulk densities against bean moisture content.

(Joshi *et al.*, 1993) and karingda seed (Suthar & Das, 1996).

Filling angle of repose

The angle of repose (θ) for the two varieties of cowpea and their variation with moisture content are shown in Fig. 3. The angle of repose (θ) increased linearly from 27.47 to 33.18° and 26.56 to 32.29° for Asetenapa and Adom varieties respectively in the moisture range studied (Fig.3). According to Boumans (1992), the two varieties can be characterized as free flowing granular products since their angles of repose at all moisture contents studied did not exceed 38°. The relationships may be represented mathematically for the two varieties as follows:

θ (Asetenapa) = 1.835M + 25.77, with a correlation coefficient, R^2, of 0.99 and

θ (Adom) = 1.78M + 24.65, with a correlation coefficient, R^2, of 0.93. The increase in angle of repose at higher moisture contents for both varieties may be due to changes in surface roughness of the bean as it absorbed moisture. Also, with more moisture absorption, the individual beans became heavier and therefore sliding became difficult.

It was also observed that at any particular moisture content, the angle of repose for Asetenapa was greater than that of Adom. This may be due to surface roughness and relative heavier weights

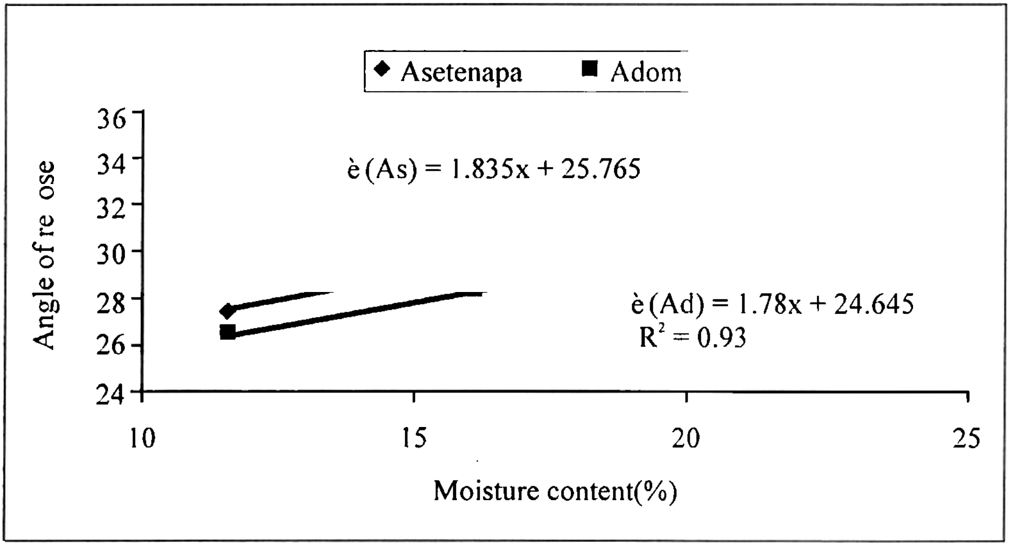

Fig. 3. Angle of repose against bean moisture content.

of the Asetenapa beans. Moisture effects on the angle of repose within the moisture range studied was found to be highly significant ($p<0.01$). Several researchers have found that the angle of repose increases linearly with moisture content for cumin seeds (Singh *et al.*, 1996), soybean (Deshpande *et al.*, 1990), sunflower seeds (Gupta and Das, 1997), coffee (Chandrasekar and Viswanathan, 1999), pumpkin seeds (Joshi *et al.*, 1993), neem seeds (Viswanathan *et al.*, 1996) and karingda seed (Suthar and Das, 1996) while non-linear variation have been found for guna seeds (Aviara *et al.*, 1999) and bambara groundnut (Baryeh, 2001).

Static coefficient of friction

The variation of coefficient of static friction with moisture content on three surfaces namely plywood, rubber and mild steel are presented in Figures 4a and 4b.

It can be seen that the coefficient of static friction is smallest for rubber and largest for mild steel for both varieties. This may be due to the smoother surface of the rubber compared with the plywood and mild steel used. Figures 4a and 4b showed again that the coefficient of static friction increased linearly with moisture content on all the three surfaces for both varieties.

The increase in coefficient of friction with moisture increase may be because, at greater moisture contents, the beans became rougher and heavier impeding sliding characteristics.

For the two varieties, the static coefficient of friction at any particular

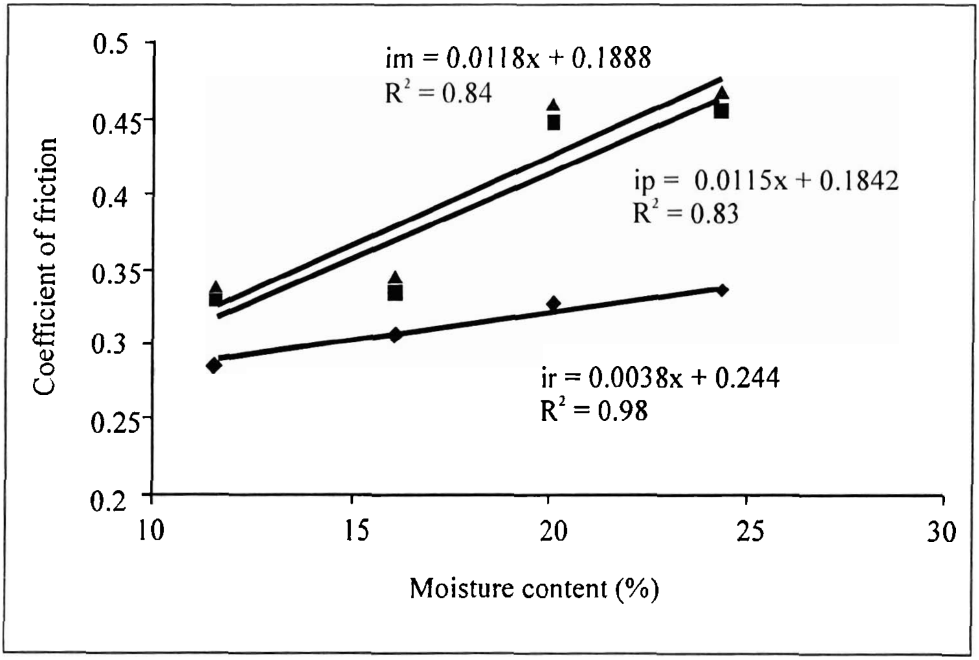

Fig. 4a. Coefficient of friction against moisture for Asetenapa.

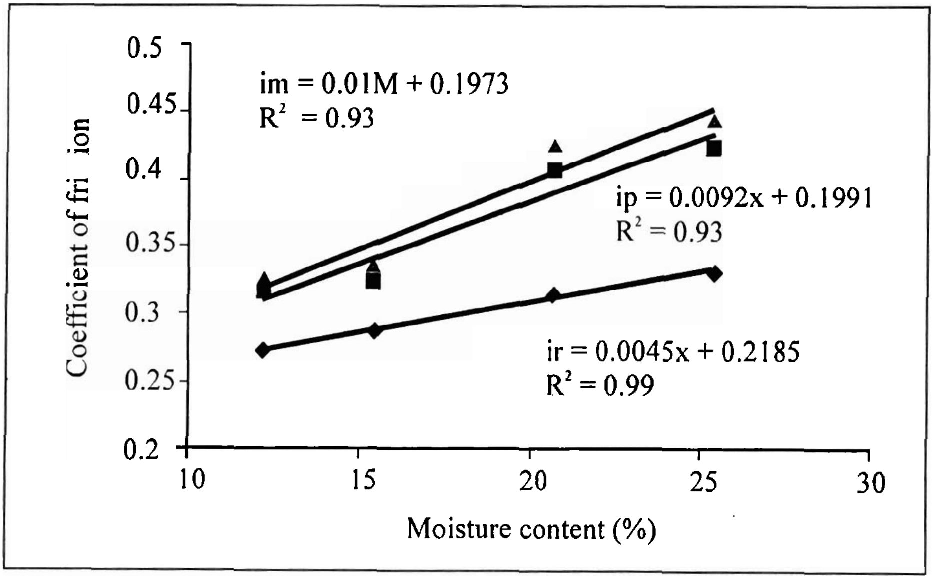

Fig. 4b. Coefficient of friction against moisture content for Adom.

moisture content for Asetenapa was greater than that of Adom on all three surfaces. Moisture content level had a significant effect ($p<0.05$) on the coefficient of static friction.

Shepherd and Bhardwaj (1986); Viswanathan *et al.* (1996); Aviara *et al.* (1999); Baryeh (2000) and Baryeh (2001) found similar increasing linear relationships for pigeon pea, lentil seeds, neem seeds, guna seeds, millet grains and bambara groundnut respectively.

Conclusions

The investigations of various physical properties of the beans of Asetenapa and Adom varieties of cowpea reveal the following:

1. The 1000-bean weight increased linearly from 125.75 to 143.85g and 147.16 to 180.14g for the Adom and Asetenapa varieties, respectively.

2. The bulk density decreased non-linearly from 792.15 to 746.75kg m^{-3} and 829.92 to 770.99kg m^{-3} for Adom and Asetenapa varieties.

3. The filling angle of repose increased linearly from 26.56 to 32.29° and from 27.47 to 33.18 for the Adom and Asetenapa varieties, respectively.

4. The static coefficient of friction increased linearly on all the three surfaces for the two varieties studied and was maximum for the mild steel and minimum for rubber at all bean moisture content studied.

5. The 1000-bean mass, bulk density, filling angle of repose and static coefficient of friction was greater for Asetenapa than Adom at all moisture contents studied. Moisture content greatly influenced the physical properties and this was found to be highly significant ($p< 0.01$) for 1000-bean mass, bulk density and angle of repose but significant ($p<0.05$) for coefficient of static friction.

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