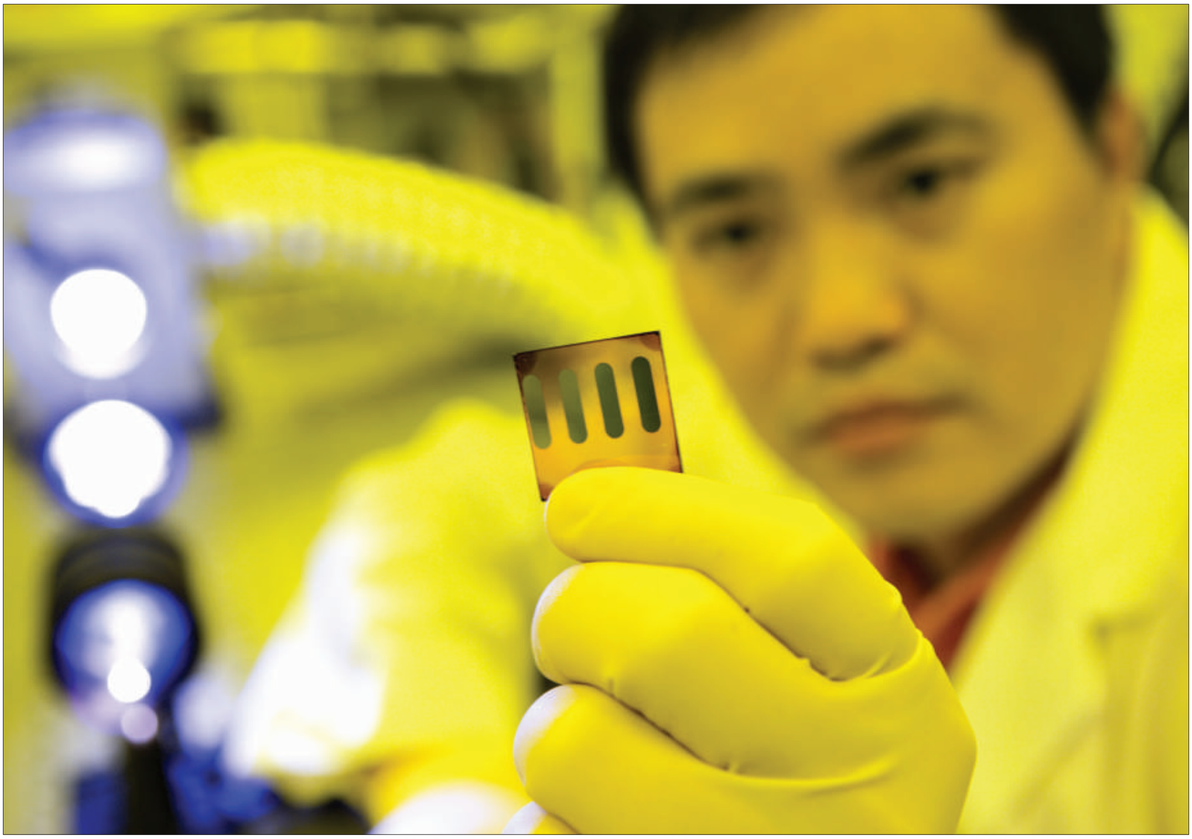

Singapore Journal of

Scientific Research

ISSN: 2010-006x

science alert

http://scialert.net/sjsr

Singapore Journal of Scientific Research 1 (3): 253-263, 2011
ISSN 2010-006x / DOI: 10.3923/sjsres.2011.253.263

Moisture-dependent Engineering Properties of Water Hyacinth Parts

[1]R.M. Davies and [2]U.S. Mohammed
[1]Department of Agricultural and Environmental Engineering, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria
[2]Department of Agricultural Engineering, Ahmadu Bello University, Samaru-Zaria, Nigeria Kaduna State

Corresponding Author: R.M. Davies, Department of Agricultural and Environmental Engineering, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria

ABSTRACT

The moisture dependent engineering properties of water hyacinth are not only important for the designing of different processing machines but also to provide the database relevant to handling process operations of the plant. Some engineering properties of water hyacinth parts (Leave, Stalk and Root) were investigated as a function of moisture content in the range of 8 to 52% w.b. These properties includes: Dimensions, mass, true and bulk densities, porosity, static and dynamic coefficients of friction and terminal velocity as a function of moisture content were determined using to standard methods. All experiments were replicated at least ten times. The SPSS software (version 11.5) and Microsoft excel (2003) were used for analysis of variance. The mean range of variation for three different parts of water hyacinth was about 0.048 to 0.074 g cm^{-3} for bulk density, 0.406 to 0.997 g cm^{-3} for particle density and 69.6 to 91.6% for porosity. The static and dynamic coefficient of friction of water hyacinth parts on four surfaces namely, glass, rubber, plywood and fibreglass were studied. The observed values for terminal velocity, coefficient of static and dynamic friction for the three different parts of the water hyacinth were statistical important at 5% probability levels for all the studied moisture contents. These findings could therefore, be used in designing and manufacturing of separators, conveyors and as well as estimating the quantity and the pressure on the bins of storage structures.

Key words: Water hyacinth, porosity, geometric, friction, properties and static

INTRODUCTION

Water hyacinth is a floating aquatic plant with fibrous root system and dark green rounded leaves. The stalks are swollen into spongy, bulbous structure. The stalks and the leaves contain air filled tissue which enable them to float on water (Olal *et al*., 2001). He described water hyacinth as the most predominantly, persistently and troublesome aquatic weed in the world and has posed ecological and biological problem in several countries of the world. He further reiterated that the main contributory factor to failure of water hyacinth harvesting machinery is the large quantity of volume and moisture content. This immensely reduces the efficiency by increasing requirement for handling and transport. Agricultural wastes are potentially huge source of energy-giving materials. They are all forms of plant-derived materials that can be used for energy. These include wood, herbaceous and aquatic plants, crop and forest residues, animal wastes, etc., Moisture plays an important role in processing agricultural products. It has a significant effect on the level of mechanical damage especially during processing operations, ability of the plant to flow on surface during conveyance, air separation during cleaning and sorting operations. It is therefore, necessary to know the engineering properties of water hyacinth at different moisture level (Davies and Zibokere, 2010).

One way to increase the utilization of water hyacinth is to turn its apparent disadvantage into opportunities and that everyone wins when we turn this terrible weed into biofuel, organic fertilizer, livestocks feed or furniture is a laudable achievement. Ghosh *et al.* (1984) reported that water hyacinth petiole (stalk stem) appears better suited to the fabrication of particle board. One alternative approach has been its incorporating into cement (reinforce) pressed board or into waxed paper. Ndede (2002) reported a total loss of water as a result of evapotranspiration from water hyacinth is about 711, 289 m^{-3} per annum. Olal (2005) reported that fresh water hyacinth has around 92% moisture content with the bulk density of 96 kg m^{-3}. The study of physical, frictional and the aerodynamic properties of water hyacinth are not only useful to the designing of different processing machines, but also to provide the database of the plant. Such engineering data of the water hyacinth is essential for design, manufacturing, development, control and evaluation of its machinery, including harvesting, conveying, separating, grading, sorting, drying and packing machines. Thus, this study was carried out to evaluate some moisture dependent engineering properties of water hyacinth plant parts relevant to post harvest handling and process operations namely bulk density, true density, porosity, terminal velocity, static and dynamic coefficient of friction and weighing property.

MATERIALS AND METHODS

Sample preparation: The study area is Port-Harcourt, Niger Delta and is located between Latitudes 4°2" and 6°2" North of the equator and Longitudes 5°1" and 7°2" East of the Greenwich meridian. This research project was conducted from October to December, 2010.The sample was harvested manually using dragging net. The sample was kept inside the polythene bags containing water. This was done to keep them alive, fresh and to avoid wilting by enabling a fairly constant water content that simulate the field conditions (Akendo *et al.*, 2008). This was taken directly to the laboratory within the shortest period of time to determine initial moisture content. Water hyacinth will be cleaned to devoid of foreign matters (i.e., stone, dust and plant materials) prior drying. The initial moisture content of water hyacinth was determined by using oven dry method at 103±2°C until constant obtained (ASABE, 2003).The values of moisture content for different part of water hyacinth ranges from 8-52%w.b.

Geometrical characteristics determination: The principal dimensions of water hyacinth parts were determined from 100 whole water hyacinth plant. The linear dimensions of leaves, stalks and roots were determined using vernier caliper and flexible metre. The measurements were replicated ten times.

The mass of water hyacinth parts: One hundred water hyacinth plants were randomly selected and fractionated into leaves, stalks and roots. The mass of water hyacinth parts was determined using a digital electronic balance with an accuracy of ±0.01. Each measurement was replicated 10 times (Davies and Zibokere, 2010).

True and bulk densities: The bulk density of three parts of water hyacinth was determined using mass volume ratio relationship. The true density was determined by using toluene (C_7H_8) displacement method (Tunde-Akintunde *et al.*, 2007; Davies, 2010).

Porosity: Porosity of the three different parts of water hyacinth at different moisture content was calculated from true and bulk density relationship given by Deshpande *et al.* (1993).

Static and dynamic coefficients of friction: The static coefficient of friction of the three different parts of water hyacinth at five different moisture content with respect to four different surfaces namely glass, glass fibre, plywood and rubber were determined using standard method (Tunde-Akintunde *et al.*, 2007). By using adjustable inclined plane attached with a protractor. The samples were placed on the covered surface with a sheet of the material. The surface was raised slightly until samples started to slide down (Dutta *et al.*, 1988). The angle of inclination was recorded and the static coefficient of friction was determined.

The dynamic coefficient of friction was determined using method adopted by Amin *et al.* (2004).

Terminal velocity determination: The method of Tunde-Akintunde *et al.* (2007) was used to determine the terminal velocity of three different parts of water hyacinth using the floating method. The variable air stream could be provided by changing the frequency of electric motor supplier. Terminal velocity which is the value of air speed at the time of floating was measured by a digital hot wire anemometer with an accuracy of 0.1 m sec^{-1}. The experiments were carried out in twelve different levels of moisture contents for three parts of water hyacinth including leave, stalk and root. The moisture contents ranged from 8 to 52% w.b. for leave, stalk and root, respectively.

Statistical analysis: All experiments were replicated at least ten times. The SPSS software (version 11.5) and Microsoft excel (2003) were used for analysis of variance (one way ANOVA), Coefficient of multiple determination (R^2) calculation of the mean, minimum, maximum, standard deviation and regression analysis of resulted data.

RESULTS AND DISCUSSION

Water hyacinth parts dimensions: The mean dimensions of water hyacinth parts at initial level of moisture content are presented in Table 1. The average values for the length, width and thickness of leaves were 7.25, 4.75 and 0.43 mm, respectively. The mean values of the upper, middle and lower diameter were significantly difference at 5% probability level. Variance analysis of the data for length of the leaves, stalks and roots was significant ($p<0.05\%$). The dimensions of the water hyacinth parts are essential for harvesting, separation, sizing and sorting equipment.

Table 1: Geometrical properties of freshly harvested Water hyacinth (WH)

WH parts	Initial Mc (w.b%)	Properties	Mean	Minimum	Maximum	SD
Leaves	82.4	Length (cm)	7.25	6.83	8.67	0.26
		Diameter (cm)	4.75	3.12	5.74	0.44
		Thickness (mm)	0.43	0.33	0.78	0.02
Stalks	90.6	Length (cm)	68.33	53.56	89.41	2.74
		Du (mm)	7.10	5.42	9.23	0.16
		Dm (mm)	21.15	19.85	26.58	0.95
		Dl (mm)	26.39	24.40	31.52	1.01
Roots	73.7	Length (cm)	48.40	11.00	57.86	1.34
		Width (mm)	0.46	0.32	0.51	0.03
		Thickness (mm)	0.39	0.26	0.45	0.02

D4: Upper diameter, Dm: Middle diameter, D1: Lower diameter, Mc: Moisture content, SD: Standard deviation

Bulk and particle densities: The Fig. 1 revealed that bulk density increase linearly with increase in moisture content with strong positive correlation coefficient. The observed values for the three water hyacinth parts were significantly important at $p<0.01$. The bulk of three parts of water hyacinth increased from (0.048-0.074 g cm^{-3}) for leave, (0.217-0.303 g cm^{-3}) for stalk and (0.070-0.096 g cm^{-3}) for root, respectively as moisture content increased from 8-52% w.b. This could be attributed to moisture gain in water hyacinth parts were lower than accompanied volumetric expansion (Pliestic *et al*., 2006). Kouchakzadeh and Tavakoli (2010) also reported a positive linear relationship between bulk density and moisture content. Similar trend was observed with particle density (Fig. 2). Analysis of variance ANOVA result indicated that the differences among the moisture content level were significantly different at 5% probability level for the three parts of water hyacinth. The mean values of true densities for leaves and stalks and roots followed the similar trend with their bulk densities in the studied moisture content (Fig. 2). The true density of leaves increased linearly from 0.406 to 0.878 g cm^{-3} as moisture content increased from 8 to 52% w.b. The true density for stalks and roots increased linearly as moisture increased from 0.837 to 0.997 and 0.541 to 0.926 g cm^{-3}. This means that relative increase in the weight of leaves,

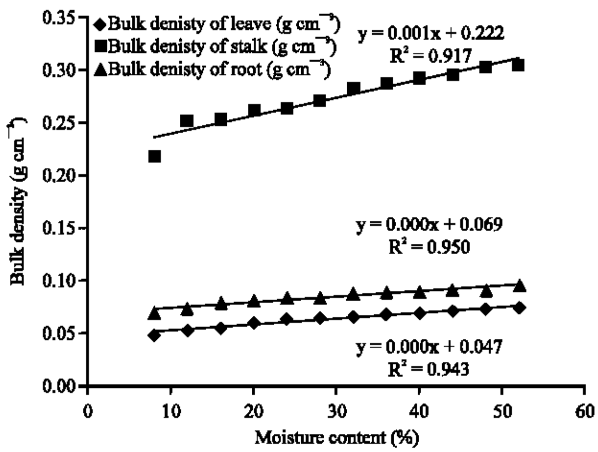

Fig. 1: Effect of moisture content on bulk density of water hyacinth parts

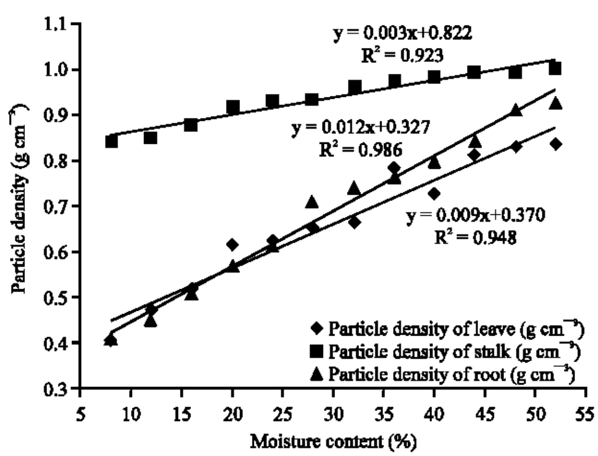

Fig. 2: Effect of moisture content on partical density of water hyacinth parts

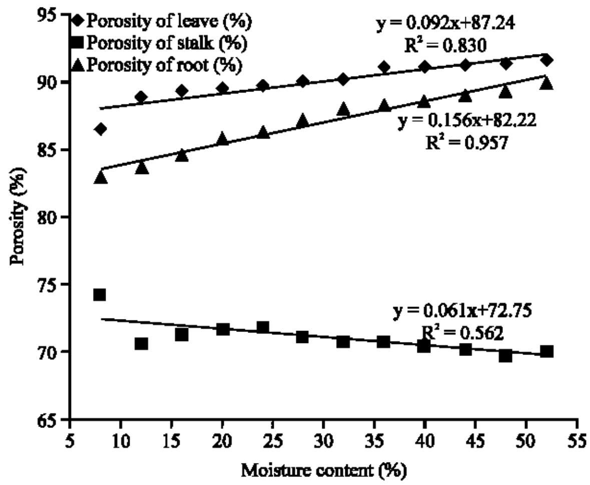

Fig. 3: Effect of moisture content on porosity of water hyacinth parts

stalks and roots are higher than the corresponding volumetric increase owing to moisture absorption. A positive correlation between the true density and moisture content was also reported for many produce including soybean (Deshpande *et al.*, 1993), pistachio (Razavi *et al.*, 2007a) and sunflower seeds (Gupta and Das, 1997). The obtained results of true density are important in a similar way to the bulk density applications for processing equipment of water hyacinth.

Porosity: The obtained results of porosity which is reliant to bulk and true densities with respect to moisture content for three different parts of water hyacinth are shown in Fig. 3. The values of porosity exhibited an increase from 86.9 to 91.6% for leave and from 69.6 to 74.1% for stalks. The porosity leave, stalk and roots increased linearly with increase in moisture contents levels. The values were significant at 5% probability level. This is a good development in drying process as the drying air would be able to travel faster through wet water hyacinth parts and remove more moisture during initial stage of drying. Similar trends have been reported for lentil seeds (Carman, 1996), sunflower seeds (Gupta and Das, 1997), white lupin (Out, 1998) and corn (Peker, 1996). In addition to design of packing equipment, knowing the property of porosity is essential for the study of air and heat flow (Pradhan *et al.*, 2009) in dryers and separators of the water hyacinth parts.

Terminal velocity: The terminal velocity of all three parts of water hyacinth increased linearly with the increase of moisture content as shown in Fig. 4. All water hyacinth parts exhibited an aerodynamic instability during experiments due to their asymmetrical and non-uniform shape (Zewdu 2007). The obtained terminal velocities ranged from 3.35 to 4.29 m sec^{-1} for leave and from 4.68 to 5.78 m sec^{-1} for stalk when the moisture content increased from 8 to 52% w.b. basis. The obtained range of terminal velocity for leave was lower than that value for the other two parts of the water hyacinth. The reason may attribute to both horizontal lying with maximum frontal area of leave against air stream. Zewdu (2007) reported the terminal velocity of the straw for the teff grain as 3.08 to 3.69 m sec^{-1}. The terminal velocity for straw material of wheat reported from 2.53 to 4.85 m sec^{-1} (Khoshtaghaza and Mehdizadah, 2006). Isik and Nazmi (2007) reported terminal velocity increase logarithmic as moisture content increased 6.20 to 7.50 m sec^{-1}. The data of

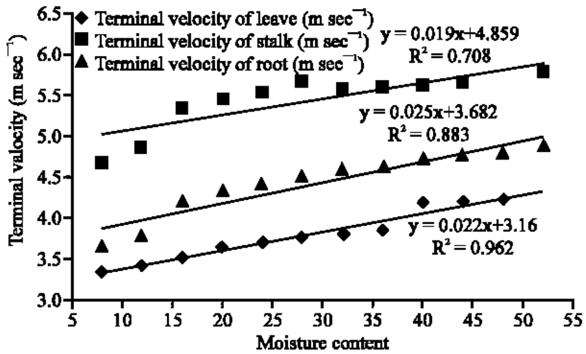

Fig. 4: Effect of moisture content on terminal velocity of water hyacinth parts

terminal velocity of different parts of water hyacinth may be used for the design and manufacturing of separators and pneumatic transporters.

Static and dynamic coefficients of friction: Figure 5 showed effect of moisture content on coefficient of static friction for water hyacinth leave determined with respect to glass, rubber, plywood and fibre glass surfaces at different moisture contents. At all the moisture contents, the static coefficient of friction of plywood recorded highest and the least was glass. This observation could be attributed to the cohesive force exerted by the water hyacinth parts on the surface of contact at higher moisture levels. The lowest and highest values of static coefficient of friction were recognized on glass and plywood sheet for leave. The positive linear relationship of static coefficient of friction with moisture content was also observed by Razavi *et al.* (2007b) for pistachio nut and its kernel and Isik and Nazmi (2007) for dent corn seeds. Figure 6 shows the static coefficient of friction for stalk with respect to glass, rubber, plywood and fibre glass surfaces at different moisture contents. The coefficient of static friction of glass ranged from 0.80 to 0.93 and rubber ranged from 1.0 to 1.3. While plywood ranged from 1.06 to 1.36 and fibre glass ranged from 0.89 to 1.07. At all the moisture contents, the static coefficient of plywood was the highest. The reason for the increased friction coefficient at higher moisture level might be attributed to the moisture adsorption by the grain creating cohesive force on the surface in contact. The static coefficient of friction increased with increase in moisture content for the four surfaces. The effect of the moisture content on static coefficient of friction on stalk of water hyacinth against glass rubber, plywood and fibre glass showed positive linear relationship. The static coefficient of friction for root of water hyacinth increased with increase in moisture content from 0.94 to 1.11 for glass, 1.22 to 1.66 for rubber, 1.24 to 1.64 for plywood and 1.00 to 1.28 for fibre glass as shown in Fig. 7. The values were significantly different ($p<0.05$). Non linear relationship between static coefficient of friction and moisture content was reported by Abano and Amoah (2011) for tiger nut. Dynamic coefficients of friction increased linearly with the increase of moisture content for leave as shown in Fig. 8. Plywood showed the highest dynamic coefficient of friction (1.18) at 52% moisture content. Figure 9 showed the effect of moisture content on the dynamic coefficient of friction. The highest and lowest values of dynamic coefficient of friction for stalk were observed for glass (0.73, 8% w.b.) and plywood surface (1.30, 52% w.b.), respectively. The obtained results in Fig. 10 revealed that rubber had the highest value (1.59, 52% w.b.) and the least value was traceable to glass 0.86. The obtained results is helpful designing various equipment including conveyors and seperators . The lowest value of static

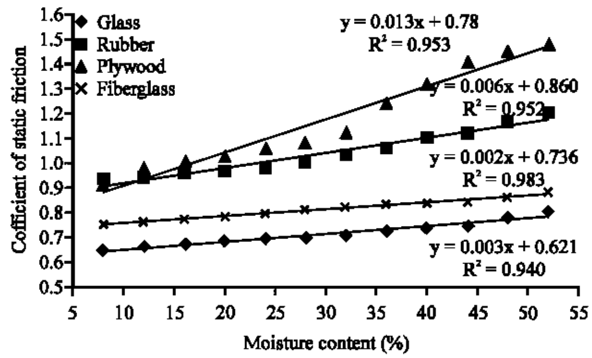

Fig. 5: Effect of moisture content on coefficient of static friction of leave

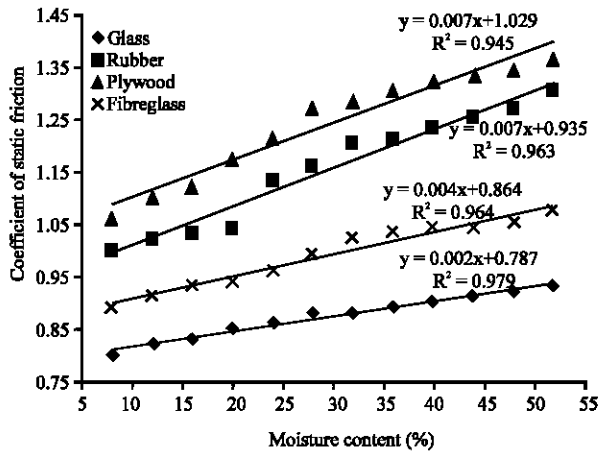

Fig. 6: Effect of moisture content on coefficient static friction of stalk

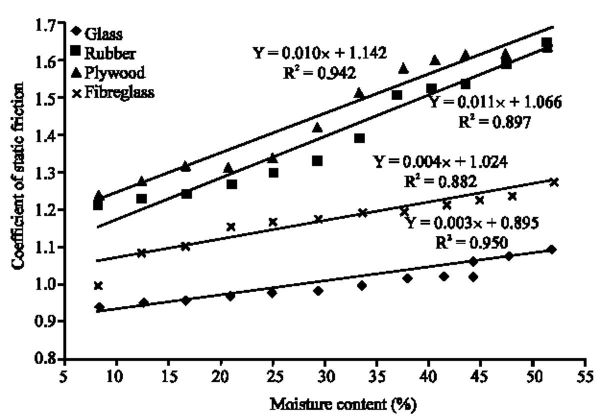

Fig. 7: Effect of moisture content on static coefficient of friction of root

coefficient of friction was observed on glass surface for all the three water hyacinth parts. The lowest and highest values of dynamic coefficient of friction belonged to leaves 0.60, on glass and root 1.19, for plywood sheet, respectively. The obtained results of friction coefficients of water hyacinth parts can be used for design of various equipment such as conveyors, sorting and seperators.

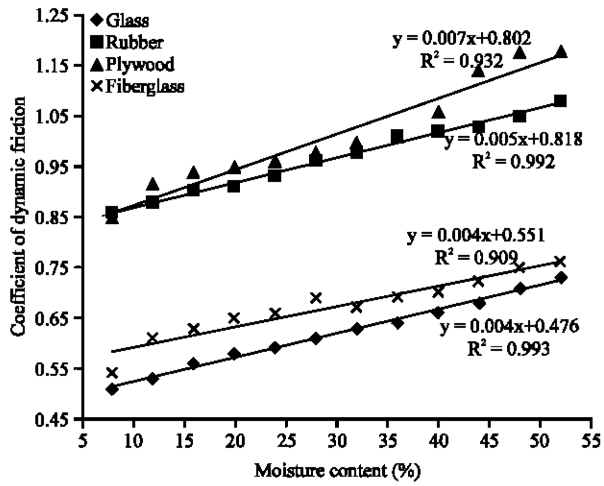

Fig. 8: Effect of moisture content on coefficient of dynamic friction of leave

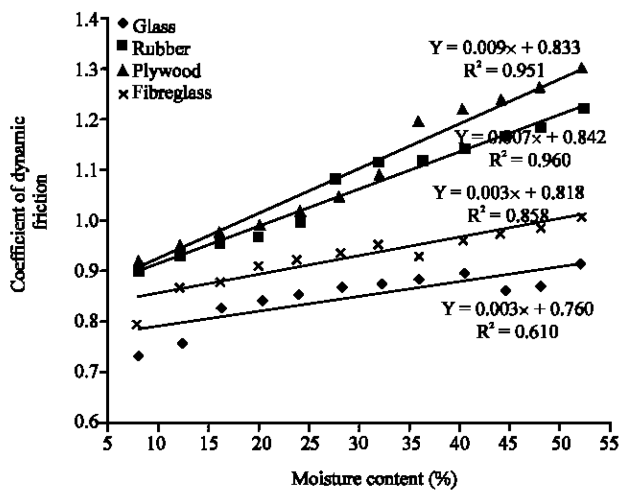

Fig. 9: Effect of moisture content on coefficient of dynamic friction of stalk

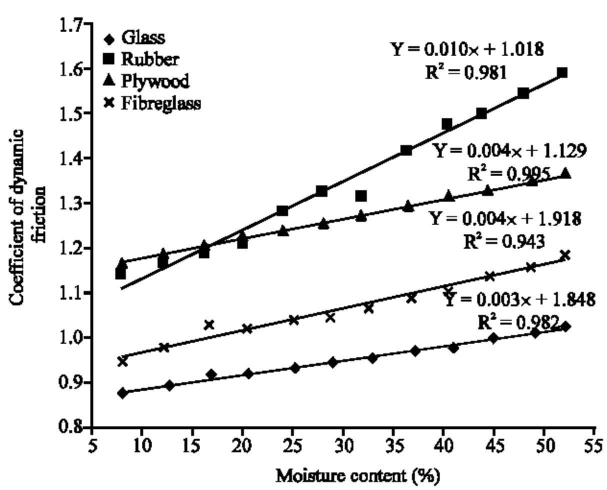

Fig. 10: Effect of moisture content on coefficient of dynamic friction of root

Table 2: Weight properties of 100 randomly selected freshly harvested water hyacinth

Property	Average	Min.	Max.	SD
Weight of whole wwh (g)	274.40[a]	201.93[i]	394.77[ae]	27.12
Weight of leave (g)	47.81[b]	31.24[h]	58.19[be]	7.03
Weight of stalk (g)	122.46[c]	98.59[ef]	161.95[cf]	14.56
Weight of root (g)	104.13[d]	72.10[ee]	124.63[ie]	9.27
Leaves\wwh (%)	17.42[e]	15.47[fg]	16.88[ed]	1.19
Stalk\wwh (%)	44.63[f]	48.82[gh]	46.97[fe]	2.14
Roots\wwh (%)	37.94[g]	35.71[ij]	36.15[ge]	2.23

wwh: Whole water hyacinth. Means showed the same alphabets are not significant at 5% probability level

Weighing properties: The weighing properties of 100 randomly selected freshly water hyacinth as a weight of whole water hyacinth, weight of leave, stalk and root the percent of leaves, stalks and roots. Percentage of leave to whole water hyacinth, percentage of root whole to water hyacinth and percentage of stalk to whole water hyacinth are presented in Table 2. The average weight of whole water hyacinth, leaves, roots and stalks were 47.81, 104.13 and 122.46 g, respectively. The corresponding values reported for 1000 grain mass of groundnut was 376 g, simarouba kernel were 330.26 (Dash *et al*., 2008) and African nutmeg 897.5 g (Burubai *et al*., 2007).

The average value of leave to whole water hyacinth, stalks to whole water hyacinth and roots to whole water hyacinth were 17.42, 37.94 and 44.53%, respectively. The analysis of variance ANOVA result showed that the difference among the moisture levels were statistically significant at the level of 0.05 for the weight of the three different parts of water hyacinth.

Weight is important in estimating the quantity, pressure on the bins and the design of for strength and size of materials to utilize for construction.

CONCLUSION

Based on investigation conducted on the some engineering properties of three different parts of water hyacinth namely leaves, stalks and roots at different moisture content the following conclusion were drawn:

- The mean geometrical properties of freshly harvested water hyacinth, for the leaves, stalks and roots were significantly different ($p<0.05$)
- The mean porosity, true and bulk densities were investigated for the three different parts of water hyacinth were significantly different at 5% probability level. The weight of 100 randomly selected water hyacinth parts (leave, stalk and root) were significantly important at 1 and 5% probability levels. Weight is important in estimating the quantity, pressure on the bins and the design for strength and size of materials to utilize for construction
- The coefficient of static friction of the three different parts of the water hyacinth were determined for four different surfaces, glass, rubber, plywood and fibre glass. Glass surface was observed to have lowest static and dynamic coefficient of friction for the three parts of water hyacinth. The variation in the terminal velocity for three different parts of the water hyacinth was recorded between 3.35 and 6.85 m sec^{-1}. A linear relationship between the moisture content of water hyacinth and its engineering properties was revealed

REFERENCES

ASABE, 2003. Cubes, pellet and crumbles definitions and methods for determining density, durability and moisture content. St. Joseph, MI, America.

Abano, E.E. and K.K. Amoah, 2011. Effect of moisture content on the physical properties of tiger nut (*Cyperus esculentus*). Asian J. Agric. Res., 5: 56-66.

Akendo, I.C.O, L.O. Gumbe and A.N. Gitau, 2008. Dewatering and drying characteristic of water (*Eichhornia crassipes*) petiole. Part 1. Dewatering characteristics. Agric. Eng. Int. CIGR Ej., 10: 1-14.

Amin, M.N., M.A. Hossain and K.C. Roy, 2004. Effects of moisture content on some physical properties of lentil seeds. J. Food Eng., 65: 83-87.

Burubai, W., A.J. Akor, A.H. Igoni and Y.T. Puyate, 2007. Some physical properties of African nutmeg (*Monodora myristica*). Int. Agrophys., 21: 123-126.

Carman, K., 1996. Some physical properties of lentil seeds. J. Agric. Eng. Res., 63: 87-92.

Dash, A.K., R.C. Pradhan, L.M. Das and S.N. Naik, 2008. Some physical properties of simarouba fruit and kernel. Int. Agrophys., 22: 111-116.

Davies, R.M. and D.S. Zibokere, 2010. Effect of moisture content on some physical and mechanical properties of three varieties of cowpea (*Vigna unguiculata* (L) Walp). Agric. Eng. Int. CIGR J., Vol. 12 (In Press).

Davies, R.M., 2010. Some physical properties of Arigo seeds. Int. Agrophys., 24: 89-92.

Deshpande, S.D., S. Bal and T.P. Ojha, 1993. Physical properties of soybean. J. Agric. Eng. Res., 56: 89-98.

Dutta, S.K., V.K. Nema and R.K. Bhardwaj, 1988. Physical properties of gram. J. Agric. Eng. Res., 39: 259-268.

Ghosh, S.R., D.C. Saikia, T. Goswami, B.P. Chaliha and J.N. Baruah *et al*., 1984. Utilization of water hyacinth (*Eichhornia crassipes*) for paper and board making. Proceedings of the International Conference on Water Hyacinth, Feb. 7-11, UNEP, Nairobi, pp: 436-460.

Gupta, R.K. and S.K. Das, 1997. Physical properties of sunflower seeds. J. Agric. Eng. Res., 66: 1-8.

Isik, E. and I. Nazmi, 2007. Moisture dependent physical and mechanical properties of dent corn (*Zea mays* var. *indentata* Sturt.) seeds (Ada-523). Am. J. Food Technol., 2: 342-353.

Khoshtaghaza, M.H. and R. Mehdizadeh, 2006. Aerodynamic properties of wheat kernel and straw materials. Agric. Eng. Int. CIGR E J., 8: 1-10.

Kouchakzadeh, A. and T. Tavakoli, 2010. The effect of moisture and temperature on thermophysical properties of iranian pistachios. Am. J. Food Technol., 5: 195-206.

Ndede, H.O., 2002. Baseline survey and environmental impact assessment. The Nairobi River Basin Project-Phase II. UNEP, IUCN, January 10, 2002.

Olal, M.A., 2005. Handicrafts prepared from water hyacinth. Organic Resources Management in Kenya, perspectives and Guidelines, forum for Organic Resources Management and Agricultural Technologies (FORMAT).

Olal, M.A., M.N. Muchilwa and P.L. Woomer, 2001. Water Hyacinth, Utilizations and the Use of Waste Material for Handicraft Production in Kenya. In: Micro and Small Enterprises and Natural Resource Use. Nightingale, D.L.M. (Ed.). Micro-Enterprises Support Programme, UNRP, Nairobi, pp: 119-127.

Out, H., 1998. Some physical properties of white lupin. J. Agric. Eng. Res., 69: 273-277.

Peker, A., 1996. The determination of some physical properties of corn kernel. Selcuk Univ. J. Agric. Faculty, 10: 22-65.

Pliestic, S., N. Dobricevic, D. Filipovic and Z. Gospodaric, 2006. Physical properties of filbert nut and kernel. Biosystems Eng., 93: 173-178.

Pradhan, R.C., S.N. Naik, N. Bhatnagar and V.K. Vijay, 2009. Moisture-dependent physical properties of Jatropha fruit. Ind. Crops Prod., 29: 341-347.

Razavi, S.M.A., A. Rafe, M. Moghaddam and A.M. Amini, 2007a. Physical properties of pistachio nut and its kernel as a function of moisture content and variety. Part 2. Gravimetrical properties. J. Food Eng., 81: 218-225.

Razavi, S.M.A., B. Emadzadeh, A. Rafe and M.A. Amini, 2007b. The physical properties of pistachio nut and its kernel as function of moisture content and variety. Part 1. Geometric properties. J. Food Eng., 81: 209-217.

Tunde-Akintunde, T.Y., B.O. Akintunde and O.J. Oyelade, 2007. Effect of moisture on terminal velocity, compressive force and frictional properties of melon seed. Agric. Eng. Int. CIGR E J., 9: 1-8.

Zewdu, A.D., 2007. Aerodynamic properties of tef grain and straw material. Biosyst. Eng., 98: 304-309.