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Frictional Characteristics of Some Water Lily Pellets

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ABSTRACT

The effect of binder type and binder ratios on static and dynamic coefficient of friction were investigated for biomass pellets on four different surfaces involving stainless steel sheet, particulates board sheet, plywood sheet and rubber sheet. The pellets were produced using aquatic weeds (water lily and phytoplankton) and agricultural wastes (banana peels, cassava peels and yam peels as binders).The ratio of binding agents to water lily residue varied from 90:10, 80:20, 70:30 60:40 and 50:50of the composition fed into pelleting machine. Inclined plane with an adjustable angle of inclination was adopted for the experiment. The static coefficient of friction decreased with the increase of binder ratio. The lowest and highest values of static coefficient of friction corresponded to stainless steel sheet (at 10% binder ratio) for phytoplankton scum bonded pellets and particulates sheet (at 10% binder ratio) for cassava peel bonded pellets. Pellets produced with phytoplankton scum had the lowest static coefficient of friction on stainless steel sheet compared to other binder types. Cassava peel bonded pellets had highest values of static coefficient of friction among the binder types. Based on the obtained data stainless steel had the lowest static and dynamic coefficient of friction thus it is recommended for manufacturing of seed conveyance, hopper used in planting machines, silos and storage containers.

Keywords: *Aquatic weeds, biomass, densification, surface areas, biofuel.*

INTRODUCTION

Water lily (Nymphaea spp.) is an invasive and prolific aquatic weed that grows at extremely fast rate. It adversely affected aquatic lives, marine transportation fishing, hydro-power and irrigation schemes in the Niger Delta, Nigeria. Water lily considered as one of the major serious threat to biodiversity [1].Aquatic plant is a renewable energy source that have huge potential as energy-giving materials. The greater percentage of the people in rural areas of Niger Delta engaged in fishing as their occupation. Most of the fish processors depend majorly on mangrove trees as their firewood [2]. In Nigeria, large quantities of water lily are produced annually and are vastly under-utilized. The utilization of biomass for the production of briquettes and pellets for biofuel is sustainable and will reduced over dependent on wood felling for firewood in the rural areas, which is tantamount to deforestation. Briquettes and pellets have clean burning nature and also have the advantage of being stored for long periods of time without deterioration.

There have been a lot of concerted efforts from researchers towards the mechanization of biomass briquettes and pellets production. Biomass either from aquatic weeds or agricultural wastes offers a number of advantages compared to fossil fuels. They are renewable energy sources and also environmental friendly [3].The greater percentage of aquatic weeds and agricultural wastes produced annually in Nigeria are grossly under-used [4]. The dominant sources of biomass fuels in Nigeria are wood (firewood and charcoal), crop and wood residues, and dung [4].The production of briquettes and pellets engenders many cottage industries which include the production of screw and hydraulic presses from locally available materials, using materials like aquatic weeds, agricultural waste and sawdust, briquette production enterprise, packaging and marketing of the briquettes. The material density increase is the reason for undertaking briquettes because it is one of the important determinants in both the saving in transportation and handling cost and any improvement in combustion efficiency over the original material. Information on frictional characteristics of biomaterials are important in providing engineering data required for design and development of equipment and structures for planting, harvesting, cleaning, grading, sorting, cleaning, and packaging, handling, transportation, separation and storing [5-19].

Frictional characteristics of biomaterials are dependent on species, maturity, ripeness, moisture content, friction surface material, material porosity, velocity relative to the friction surface, orientation of the material in relation to the direction of moment, normal pressure exerted on particles, different in particle shape and size and as well as period of material storage [20-24].The frictional properties have been studied by various scientists for biomaterials on different surface materials such as water lettuce briquettes [25],fenugreek seeds [26], barberry [27], jackbean seed [28], Garlic [29], moth gram [30], coriander seeds[31], lentil seeds [32], white speckled red kidney bean grains [33] and orange [34]. The objective of this study was to determine relationship between the effect of binder ratio, binder types, static and dynamic coefficient of friction of some surface materials by water lily pellets.

Materials and Methods

The water lily was harvested from Amassoma River, Bayelsa State, Nigeria. Agricultural wastes (cassava peel, banana peel and yam peel) were collected from Swali market, Yenagoa. Phytoplankton scum was collected from Roone Fish Farm ponds. Water lily and agricultural wastes were selected and cleaned to devoid of foreign matters. The binding agents; phytoplankton scum and other agricultural wastes were sundried and ground to fine particle size. Water lily, cassava peel, banana peel and yam peel were sun-dried and ground to particle distribution size range 0.075- 0.500 mm. This was made possible through the use of hammer mill and as well as Tyler sieve. The percentages of binding agent used of each of the mixture were 10, 20, 30, 40 and 50%.Manually operated screw press pelleting machine was utilized for the production of pellets.

A screw press die dimension was 4.0 mm thickness and 4.5 mm in diameter was used for this study. Properly mixed ground feedstock was fed into the compression chamber (comprises of power screw and compression plate) through hopper. The power shaft was rotated in particular direction through crank arm. The operation was based on the principle of axial movement of the feedstock in the screw press. The continuous turning of the crank lever rotates the screw auger which pushes the compressed feedstock under high compression ratio through die and finally discharge sprout.

Frictional Properties

Static and Dynamic Coefficients of Friction

The static coefficient of friction (μs) of water lily pellets at four different structural surfaces and for four different binding agents were investigated according to Kaliniewicz et al.[35]. The measurement was conducted on four different materials involving stainless steel, particulate board, plywood and rubber sheets. The applied apparatus was an adjustable inclined surface equipped with a protractor. A topless and bottomless rectangular plywood frame (120 mm ×70 mm × 35 mm) was used of this experiment. It was filed with pellets and placed on different plain structural surfaces. The frame was lifted gently in order not to have direct contact with the measured structural surface. The structural surface with the frame containing pellets resting on was inclined gently and steadily with a screw device until the frame started to slide down the inclined plain and the angle was read through attached graduated scale.. The angle of inclination (α) was recorded and the static coefficient of friction (μs) was calculated from equation below:

$$\mu_s = \tan\alpha \quad (1)$$

The dynamic coefficient of friction (μd) was measured on the stainless steel, particulate board, plywood and rubber sheets based on method adopted by Amin et al.[32].

Moisture Content Determination

The moisture content of the mixed feedstock was determined prior pellet production using ASABE [36] standard use of oven-drying method.

Results and Discussion

The fifty (50) properly formed pellets samples were randomly selected from each of the binder types and binder ratio to obtain data on the frictional properties. The coefficient of static friction of phytoplankton scum bonded pellets

(Fig. 1) varied between 0.27(±0.04) (B5) and 0.33(±0.01) (B1) on stainless steel sheet surface, 0.433±0.03 (B5) and 0.41(±0.04) (B1) on particulates sheet, 0.30(±0.03) (B5) and 0.35(±0.02) (B1) on plywood sheet, 0.33(±0.01) (B5) and 0.39 (±0.05) (B1) on rubber sheet. The static coefficient of friction decreased with the increase of binder ratio.

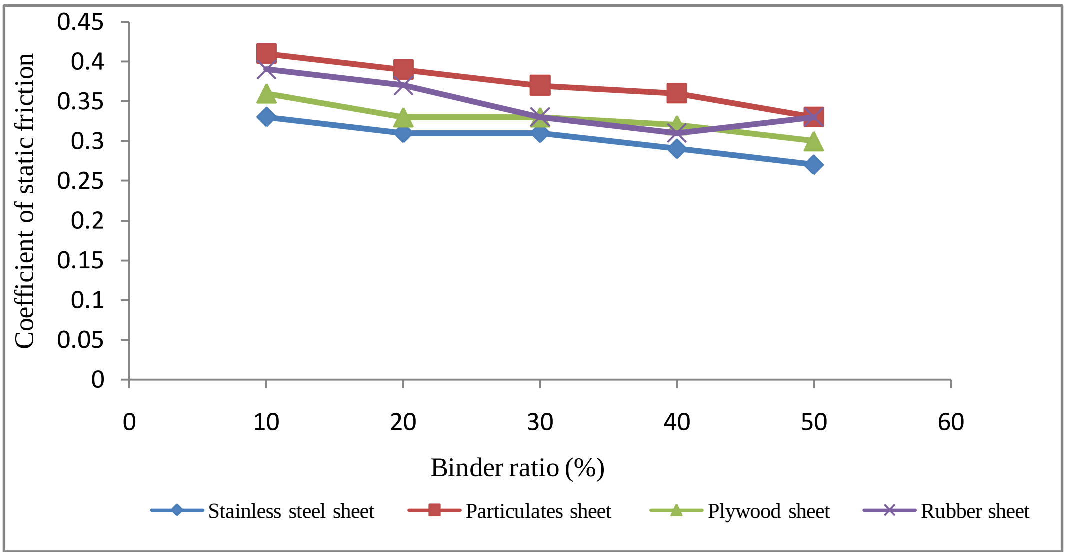

Figure1. *Coefficient of static friction of phytoplankton scum bonded pellets*

The coefficient of static friction of yam peel bonded water lily pellets varied between 0.29±0.03 (B5) and 0.34±0.01 (B1) on stainless steel sheet surface, 0.37±0.04 (B5) and 0.43±0.03 (B1) on particulates sheet,0.30±0.02 (B5) and 0.37±0.03 (B1) on plywood sheet, 0.32±0.06 (B5) and 0.38±0.02 (B1) on rubber sheet (Fig. 2). The corresponding coefficient of static friction of yam peel bonded water lettuce briquettes varied between 0.13±0.04 (B5) and 0.23±0.03 (B1) on fibreglass surface, 0.21(±0.06) (B5) and 0.4 ±0.02 (B1) on rubber, 0.14±0.02 (B5) and 0.36±0.03 (B1) on plywood, and 0.19±0.03 (B5) and 0.31±0.01 (B1) on aluminium sheet [25]. The coefficient of static friction on rubber surfaces was reportedly higher than that of plywood sheet [10, 11, 19, 38, 39, 40, 41, 42]. Thus, it is recommended to use stainless steel sheet as structure material in the production of seed hopper in planters, silos and storage containers.

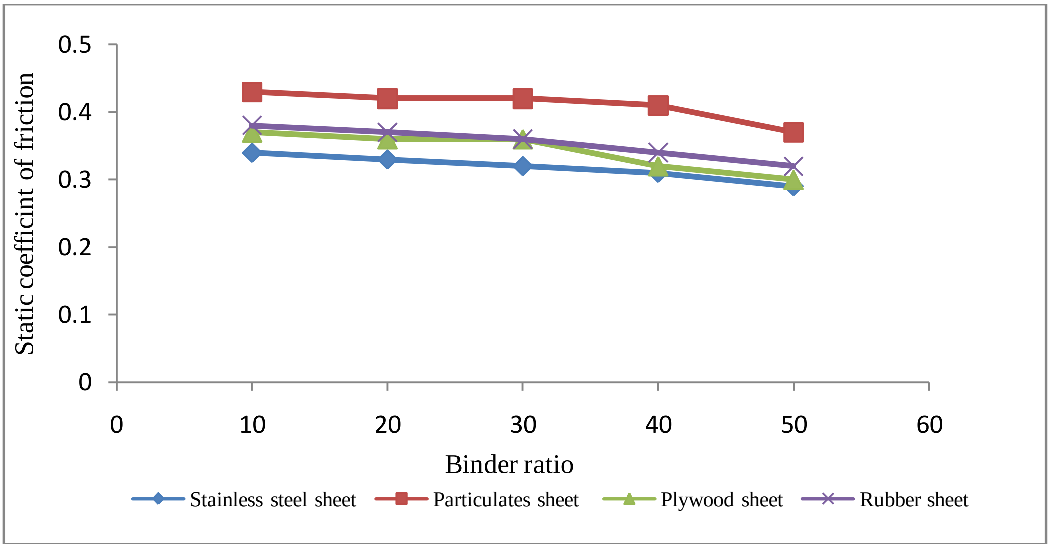

Figure2. *Coefficient of static friction of yam peel bonded pellets*

The coefficient of static friction of banana peels bonded pellets was determined for four different surfaces. It was revealed that the lowest and the highest coefficient of static friction corresponded to stainless steel sheet and particulate board as revealed in Fig. 3.

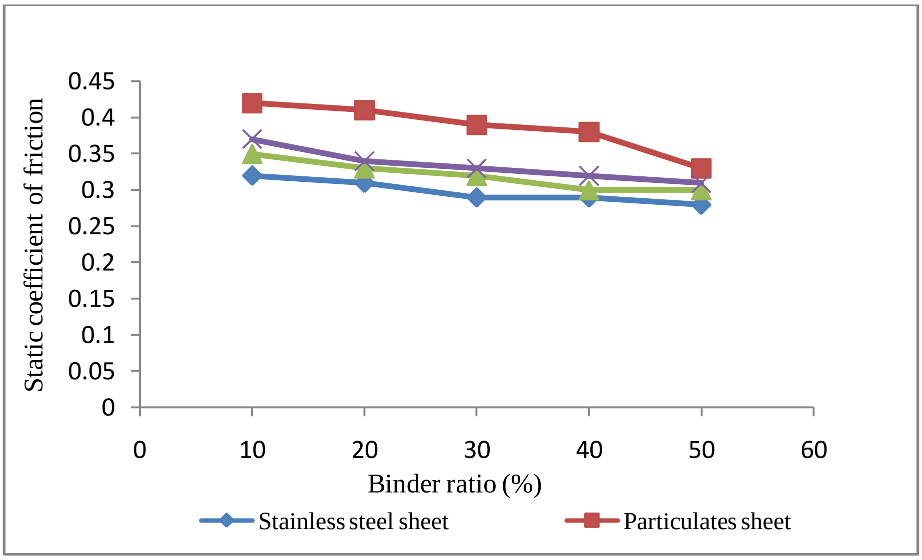

Figure3. *Coefficient of static friction of pellets produced from banana peel*

Cassava peel bonded water lily pellets had highest value of static coefficient of friction among the binder types (Fig. 4). The obtained data showed that it is recommended to use the stainless steel than using plywood, particulate board and rubber sheet in the production of seed hopper used in planting machines, silos and storage containers.

The present result on static coefficient of friction of pellets on different materials is much higher than the corresponding static friction coefficient of two plum cultivars that varied from 0.067 to 0.276 on galvanized iron, 0.082 to 0.277 on rubber, and 0.073 to 0.271 on plywood [43]. But, less than corresponding static coefficient of friction of Egyptian onion cultivars varied between 0.67 and 1.34. The briquettes produced from water lettuce and banana peel had coefficient of static friction ranged between 0.19±0.01 (B5) and 0.29±0.06 (B1) on fibreglass surface, 0.31±0.03 (B5) and 0.46 ±0.02 (B5) on rubber, 0.24±0.02 (B5) and 0.42±0.03 (B5) on plywood, and 0.19±0.03 (B5) and 0.31±0.01 (B1) on aluminium sheet [25].

It was observed that coefficient of static friction of stainless steel, particulate board, plywood and rubber sheet surfaces correlated negatively and significantly with the binder ratios (10%, 20%, 30%, 40% and 50%) and binder types (phytoplankton scum, yam peel, banana peel and cassava peel) as shown Table 1.

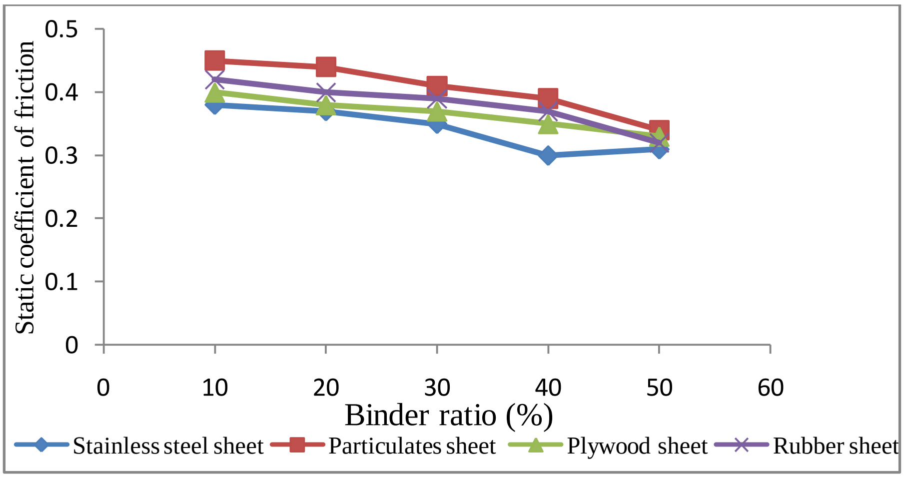

Figure4. *Coefficient of static friction of cassava peel bonded pellets*

Negative linear relationship was revealed between the coefficient of static friction of pellets on all the tested surfaces and the binder ratios for all the binder types (Table 1). The reason for this observation may be attributed to the fact that at higher binder ratio the pellets become smoother, glossier and cohesive. The lowest and highest values of static coefficient of friction corresponded to stainless steel sheet (at 10% binder ratio) for phytoplankton scum and particulates sheet (at 10% binder ratio) for cassava peel (Fig. 1 and Fig. 4). Pellets produced with phytoplankton scum had the lowest static coefficient of friction on stainless steel sheet compared to other binder types investigated. Based on the data obtained the surface of the stainless steel gives the lowest values of coefficient of friction and thus, its utilization is highly recommended as constructional material for conveyance system, separators, silos and storage containers. Stainless steel was recommended among the various surface material investigated for constructional material for the development of equipment for screw conveyor system, seed hopper in planters, silos and storage containers [37].

Table1. *Regression equations correlated to static coefficients of friction of pellets*

Binder Types	Surfaces	Equation	R^2
Phytoplankton scum	Stainless steel sheet	μ_s =-0.001B_R + 0.444	0.942
	Particulates sheet	μ_{PP}=-0.001B_R + 0.529	0.981
	Plywood sheet	μ_{PW}=-0.001B_R + 0.500	0.750
	Rubber sheet	μ_{RS}=-0.001B_R + 0.467	0.898
Yam peel	Stainless steel sheet	μ_s =-0.001B_R + 0.454	0.973
	Particulates sheet	μ_{PP}=-0.001B_R + 0.549	0.768
	Plywood sheet	μ_{PW}=-0.001B_R + 0.496	0.890
	Rubber sheet	μ_{RS}=-0.001B_R + 0.499	0.969
Banana peel	Stainless steel sheet	μ_s =-0.001B_R + 0.428	0.925
	Particulates sheet	μ_{PP}=-0.002B_R + 0.549	0.896
	Plywood sheet	μ_{PW}=-0.001B_R + 0.459	0.938
	Rubber sheet	μ_{RS}=-0.001B_R + 0.476	0.896
Cassava peel	Stainless steel sheet	μ_s =-0.002B_R + 0.505	0.868
	Particulates sheet	μ_{PP}=-0.041B_R + 0.627	0.763
	Plywood sheet	μ_{PW}=-0.001B_R + 0.519	0.989
	Rubber sheet	μ_{RS}=-0.002B_R + 0.549	0.912

The dynamic coefficient of friction decreased with the increase of binder ratio (Fig. 5). Negative linear relationship was established between dynamic coefficient of friction of pellets on all the tested surfaces and the binder ratios for all the binder types. The average dynamic coefficient of friction of pellets is less than static coefficient of friction for all the binder ratios and tested surfaces.

The correlation coefficient was determined between coefficient of dynamic friction of stainless steel, particulate board, plywood and rubber sheet surfaces, binder ratios and binder types (Table 1).

The demonstrated relationship was strong negative and significant and the values varied between 0.750 and 0.989 (P<0.001).

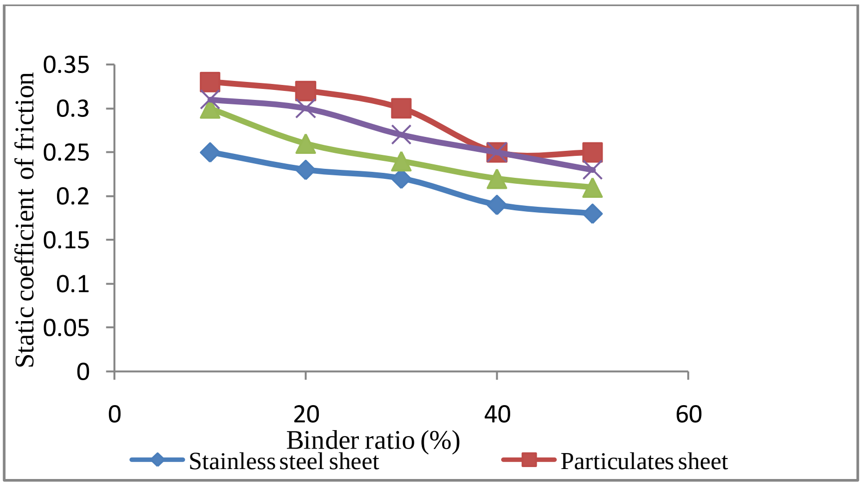

Figure5. *Coefficient of static friction of phytoplankton scum bonded pellets*

The lowest and highest values of dynamic coefficient of friction for yam bonded pellets corresponded to stainless steel sheet (at 10% binder ratio) and particulates sheet (at 10% binder ratio) Fig. 6. Particulate board sheet had the highest surface roughness with respect to other structural materials.

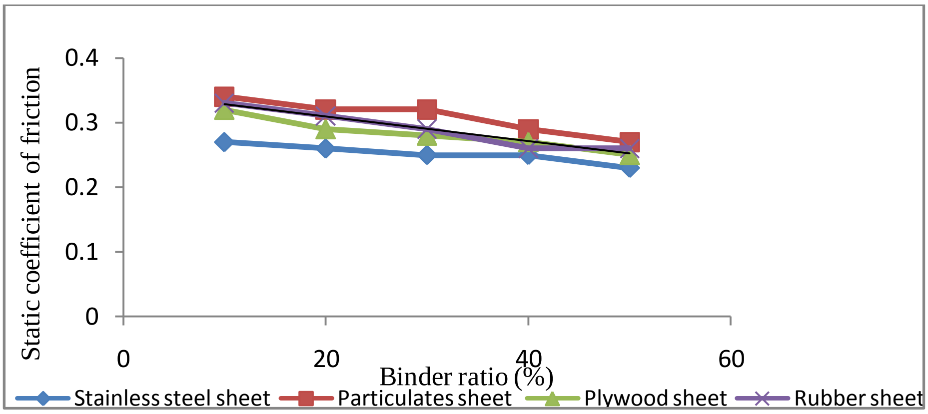

Figure6. *Coefficient of dynamic friction of yam bonded pellets*

The dynamic coefficient of friction decreased with the increase of binder ratio (Fig. 7). The average dynamic coefficient of friction of pellets is less than static coefficient of friction for all the binder ratios and tested surfaces. The coefficient of dynamic friction of stainless steel, particulate board, plywood and rubber sheet surfaces, binder ratios and binder types.

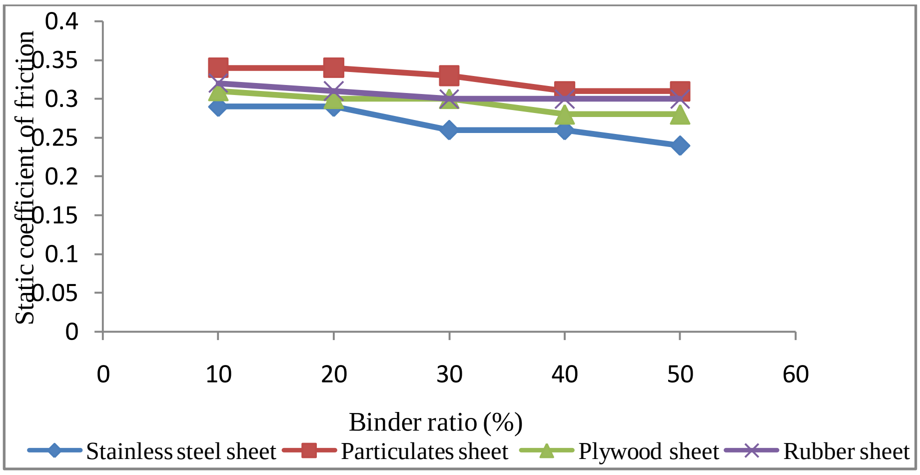

Figure7. *Coefficient of dynamic friction of banana bonded pellets*

The dynamic coefficient of friction of cassava bonded pellets decreased with the increase of binder ratio (Fig. 8). The mean dynamic coefficient of friction of pellets is less than static coefficient of friction for all the binder ratios and tested surfaces. Particulate board sheet had the highest dynamic coefficient friction because it had greatest surface roughness with respect to other structural materials. This parameter is important for designing pneumatic conveying systems, screw conveyors, hoppers.

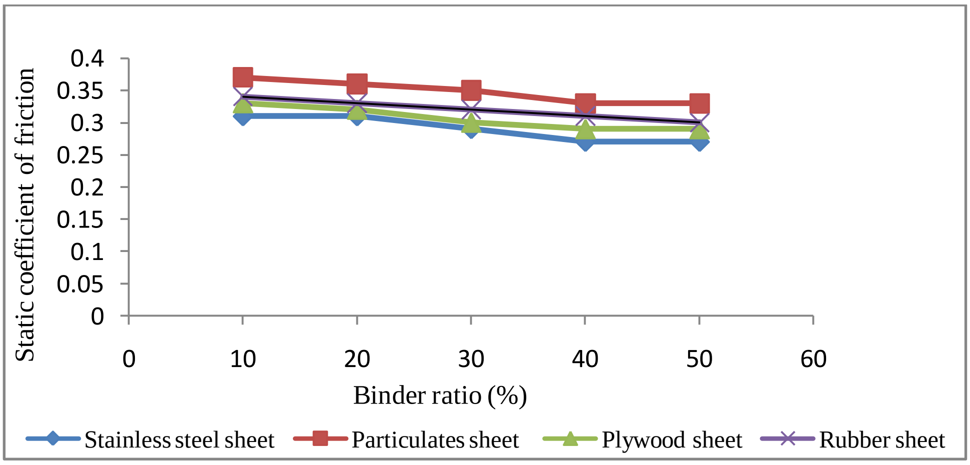

Figure8. *Coefficient of dynamic friction of cassava bonded pellets*

CONCLUSION

Stainless steel had the lowest values of static coefficient of friction thus, it is recommended among the various surface material investigated as constructional material for the development of equipment for pneumatic conveying systems, screw conveyors, separators, seed hopper in planters, silos and storage containers. Particulates sheet posed the greatest resistance to the movement of all pellets and thereby had the maximum static coefficient of friction. The coefficient of static coefficient of friction varied between 0.27 and 0.45 for all the binder ratios and binder types and surfaces. The highest static coefficient of friction corresponded to particulate surface followed by the rubber, plywood and stainless steel surfaces. Negative linear relationship was revealed between the coefficient of static friction of pellets on all the tested surfaces and the binder ratios for all the binder types. The correlation coefficient between coefficient of dynamic friction of stainless steel, particulate board, plywood and rubber sheet surfaces, binder ratios and binder types investigated was strong negative and significant and the values varied between 0.750 and 0.989. Particulate board sheet had the highest static and dynamic coefficient friction because it had greatest surface roughness with respect to other structural materials. These parameters are important for designing pneumatic conveying systems, screw conveyors and hoppers.

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