EFFECT OF SOME PROCESSING VARIABLES ON ANGLE OF REPOSE AND COEFFICIENT OF FRICTION OF DRIED FERMENTED CASSAVA GRANUES

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ABSTRACT

The angle of repose and coefficient of friction gain importance during food handling, storage, processing and during process of designing these type of machines. Therefore, this study was conducted to investigate the effect of some processing variables; drying temperature, dewatering pressure, size reduction and fermentation period on angle of repose and coefficient of friction of dried fermented cassava crumbles. A 2^4 factorial experiment was design to investigate the effect of these variables on the coefficient of friction and angle of repose. Each variables was examine at two levels; drying temperature (50^0C and 80^0C), dewatering pressure (5MPa and 10MPa), size reduction (Hammer mill and Renting in water) and fermentation periods (3days and 5days) yielding 16 experimental samples. The data were statistically analyzed using Yates algorithm. The results obtained showed that the coefficient of friction on wood is higher than the coefficient of friction on steel. A change in drying temperature from 50^0C to 80^0C increase coefficient of friction by 19% on wood, while hammer milling the fresh cassava root before fermentation increase the coefficient of friction on steel by 7.5%. All the two, three and four interaction effect were pulled together to test the significance of the main effect. It was found that drying temperature and fermentation period was significant at 1% level on steel, while only drying temperature was significant at 1% level on the wood. However, it was found that a change in fermentation days from 3 days to 5 days reduces the angle of repose by 10%.

Key words: Angle of repose, Coefficient of friction, Drying temperature, Size reduction. Fermentation period, Dewatering pressure.

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INTRODUCTION

Cassava *(Manihot Esculenta Crantz)* is sometimes classified as a crop for developing countries and for consumption only by rural people whereas the large crop of cassava grown annually in the tropics is actually consumed in all its forms by nearly all income levels. It has been reported that Nigeria with annual production of about 42 million metric tones of cassava roots is the largest producer in Africa (CBN 2003). An estimated 157 million tones of cassava roots were produced in 1990 (Annon, 1990). Human consumption accounts for 60% of production; the remaining is being used as animal feed or in industry (Cooke and Cock, 1989).

Cassava being a highly perishable crop is very difficult to store fresh. About 23% of cassava harvest is usually lost due to food deterioration of the roots. In many West African Countries cassava processing is a female dominated house hold enterprise using traditional methods. At present, the demand for cassava products far outstrips the annual production because of new openings for cassava exportation (Aderinola *et al* 2006). Increase in demand for the cassava products as food and feeds calls for better ways of handling and processing cassava.

In the processing of cassava into dried fermented cassava flour, following processing variables are involved; fermentation period, drying temperature, dewatering pressure and size reduction.

To design effective handling equipment for cassava processing, the knowledge of the angle of repose and coefficient of friction is useful (Ezeaku 1996; Dakogoi 2001). The nature and the behaviour of agricultural materials make it imperative for specific experiments to be conducted and the data so generated are based on the peculiarities of the production processes and the type of product. The coefficient of friction is a major index indicating incidence of motion. It is the angle measured from the horizontal at which a granular material will begin to slide and/or role upon itself after it has been allowed to consolidate. (Mohsenin, 1986; Herderson and Perry 1982; Umugbai 2005). The flow of a granulated or unconsolidated material from a bin by gravity or a loaded auger started by power source depends on static friction. The knowledge of coefficient of friction is useful in design of storage structures, hoppers, material handling equipment, and separators base on difference in surface texture of materials.

The angle of repose is needed as baseline data in optimal design of machines handling and storage of agricultural material. Also, in the design of some agricultural handling machine and storage bin for dried cassava root; the engineer will need some information on the angle of repose of dried cassava root. Granular material exhibits some frictional properties between itself and the bulk and between the surface over which they flow on the other hand. This paper presents results on the effect of some processing variable; drying temperature, dewatering pressure, size reduction methods and fermentation period on the coefficient of friction and angle of repose of dried fermented cassava granules. Methods employed were selected for simplicity, accuracy of results and wide acceptability.

EXPERIMENTAL PROCEDURE

Sampling Technique

Freshly harvested cassava tubers were bought from Igbara-Oke Central Market in Ifedore Local Government of Ondo State, Nigeria. The cassava was planted in March 2003 and harvested in November, 2005.

Experimental Design

Some noticeable processing variables that might influence the mechanical properties of dried fermented cassava root are drying temperature, size reduction, dewatering pressure and fermentation time. In order to determine the main effects and interaction effect of factors on angle of repose and coefficient of friction of dried fermented cassava flour. A 2^4 factorial experiment was designed (Table1) to investigate the effect of the processing variables selected ,viz; drying temperature (50^0C and 80^0C); dewatering pressure (5MPa and 10MPa); size reduction methods (Hammer mill and Renting in water) and fermentation period (3 days and 5days) .

Processing

The roots were peeled and washed manually. The range of factors considered for this were selected based on the review of literature and preliminary laboratory investigations.

Size Reduction

Two methods of size reduction were applied on the fresh cassava; reduction by mechanical means using Hammer mill that was fabricated at the Department of Agricultural Engineering, Obafemi Awolowo University, Ile-Ife and renting in water.

Fermentation Conditions

The samples prepared above were divided into two, one part was allowed to ferment for 3 days and another allowed fermenting for 5 days. The fermentation was done at the room temperature of $30^0C \pm 2^0C$.

Dewatering Pressure

Removal of water by pressing as an aid to the dehydration was done by applying pressure of 5MPa and 10MPa using a laboratory hydraulic press fabricated at Agricultural Engineering Department, Obafemi Awolowo University ,Ile-Ife, Nigeria .

Drying Temperature

Each sample prepared above was divided into two, one dried at temperature of 50^0C and another dried at temperature of 80^0C in the shelves of a Galenkamp moisture extraction oven. The drying of the fermented cassava granules was done using a tin layer of about 200g of fermented cassava crumbles spread on stainless steel trays and placed in the shelves of the oven. Drying was deemed to be completed when there was no further loss in weight after three consecutive interval reading.

Static Coefficient of Friction

The static coefficient of friction of cassava granule on two structural surfaces, namely, plywood and galvanized sheet metal were measured using the inclined plane apparatus (Figure1). For this measurement one end of the friction surface was attached to an endless screw. The dried fermented cassava granules were placed on the surface and were gradually raised by the screw. The angle between the surface and the horizontal were read when the dried fermented cassava granules started sliding over the surface. The tangent value of the angle measured was taking to be the coefficient of static friction of the dried fermented cassava granules. This method has being used by other researchers (Bargeh 2001; Dutta *et al* 1988; Ajao 2007; Musa O. Zean and Heciseferogullari 2004).

Angle of Repose

Angle of repose is the angle with the horizontal at which the material will stand when piled. The angle of repose (θ) was determined by filling a 100 mm diameter and 600 mm long topless and baseless cylinder with dried fermented cassava granule and gently lifted to allow the sample to form a cone. The diameter and the height of the cone were measured and the angle of repose was calculated thus:

$$\theta = tan^{-1}\left\{\frac{2H}{D}\right\}$$

Where H is the height of the cone and D is the diameter of the cone. This method has being used by Ajao 2007; Ozguven and Kubilay 2004.

The result of this experiment was statistically analyzed using Yates algorithm to determine the main and interaction effect of drying temperature, size reduction method, fermentation time and dewatering pressure on the angle of repose.

RESULTS AND DISCUSSION

Effect of Processing Factors on Coefficient of Friction

The result of effect of processing variables on coefficient of friction on wood and steel was investigated. The result of the experiment is as shown in Table 2. It was found that drying temperature, size reduction method and dewatering pressure have effect on the coefficient of friction of dried fermented cassava granule on wood in the range of temperature considered. Contrary to expectation , it was found that at higher temperature the coefficient of friction was high. This may be due to an observed static electricity which increased with drying temperature in the dried fermented cassava crumbles . This may need further research work to verified types of charges involved. The higher the drying temperature the lower the final moisture content and the higher the coefficient of friction in the range of temperature considered, Musa Ozcan and Haciseferogullari 2004(13) reported a similar result. The observed coefficient of friction for dried fermented cassava crumbles was in the range found in literature for other biomaterials like Terebinth fruit (Ayin and Ozcan, 2002), *Rhus coriaria L.* (Musa Ozcan and Haciseferogullari 2004). The result of the experiment was statistically analyzed. It was observed that only drying temperature had a significant effect on the coefficient of friction on wood Table 3. However, for steel, the analysis showed that only size reduction method had effect on the coefficient of friction. Changing from renting in water as a method of size reduction to hammer mill increased the coefficient of friction. This was more pronounced when the granules were fermented for 3days. At the 3rd day, the size of the fermented cassava granules was bigger than the size of the cassava milled with hammer mill. The bigger the size of cassava mash the higher the coefficient of friction. The effect of drying temperature was not significant on the coefficient of friction on steel in the range considered because the surface was smooth. It was observed that the surface material has a greater effect on the coefficient of friction than the processing factors Table 4. The coefficient of friction on wood is higher than on steel. The same has being observed by other researchers for other products (Musa O Zcan and Hoydar, 2004, Ajao 2007, Umogbai 2004).

Angle of repose

The results of the experiment on the effect of processing variables on angle of repose are shown in Table 5. The used of hammer mill before fermentation reduces the angle of repose. This is more pronounced when the fermentation is three days. This is because the hammer mill has reduced the size before fermentation. Hence, the resulting dried fermented cassava root has a smaller size compared with the one soaked in water. However, it was found that fermentation time reduce slitely the angle of repose. An increase in fermentation days from 3 days to 5 days reduces the angle of repose by about 10%. The results of angle of repose were similar to those found in literature for some crops (Umogbai 2004). The two, three and four interaction effect was pulled together to test the significant of the main factor. It was found that the effect of size reduction was significant at 1% probability while that of fermentation time was significant at 5% of probability Table 6.

CONLUSION

It was observed that drying temperature, size reduction method and material surface are the most significant factors that affect coefficient of friction while only the fermentation time affect the angle of repose. The coefficient of friction on wood was found to be 0.565± 0.058 and on steel was 0.45± 0.166 while the angle of repose was found to be 18.79± 0.84 in the range of factors considered. It is of opinion that the result of this work would help material handling engineers in considering the effect of processing factors in the design of cassava processing machine.

Table 1: 2^4 Factorial Experiments for Cassava Processing Variables

Sample	Temp (^{0}c)	Fermentation (Days)	D. Pressur (KN)	Size Reduction
$T_1F_1P_1R_1$	50	3	50	R. Water
$T_2F_1P_1R_1$	80	3	50	R. Water
$T_1F_2P_1$	50	5	50	R. Water
$T_2F_2P_1R_1$	80	5	50	R. Water
$T_1F_1P_2R_1$	50	3	100	R. Water
$T_2F_1P_2R_1$	80	3	100	R. Water
$T_1F_2P_2R_1$	50	5	100	R. Water
$T_2F_2P_2R_1$	80	5	100	R. Water
$T_1F_1P_1R_2$	50	3	50	H. Mill
$T_2F_1P_1R_2$	80	3	50	H. Mill
$T_1F_2P_1R_2$	50	5	50	H. Mill
$T_2F_2P_1R_2$	80	5	50	H. Mill
$T_1F_1P_2R_2$	50	3	100	H. Mill
$T_2F_1P_2R_2$	80	3	100	H. Mill
$T_1F_2P_2R_2$	50	5	100	H. Mill
$T_2F_2P_2R_2$	80	5	100	H. Mill

Drying Temperature (T_1=50^{0}C&T_2=80^{0}C); Dewatering Pressure (P_1=50KN&P_2=100KN); Fermentation priods (F_1=3days&F_2=5days); Size Reduction Method (S_1=Retting in water&S_2=Hammer milling)

Table 2: The Result of Experiment on Coefficient of Friction of Dried Fermented Cassava Granules on Steel and Wood

Sample	Temp	Size Reduction	Days	Pressure (MPa)	Friction on (Steel)	Friction on (Wood)
1	50	R. Water	3	5	0.53	0.53
2	80	R. Water	3	5	0.53	0.63
3	50	H. Mill	3	5	0.49	0.51
4	80	H. Mill	3	5	0.49	0.65
5	50	R. Water	5	5	0.53	0.53
6	80	R. Water	5	5	0.53	0.63
7	50	H. Mill	5	5	0.49	0.51
8	80	H. Mill	5	5	0.49	0.53
9	50	R. Water	3	10	0.53	0.53
10	80	R. Water	3	10	0.53	0.63
11	50	H. Mill	3	10	0.49	0.51
12	80	H. Mill	3	10	0.49	0.65
13	50	R. Water	5	10	0.53	0.53
14	80	R. Water	5	10	0.53	0.63
15	50	H. Mill	5	10	0.49	0.51
16	80	H. Mill	5	10	0.49	0.53

Table 3: Statistical Analysis of Variance Table for Effect of Processing Factors on Coefficient of Friction on Wood.

Source of Variation	Effect	Sum of Squares	Degree of Freedom	Mean of Square	F
Average	0.65	81.722			
Main Effect					
Drying Temp. (T).	0.090	0.518	1	0.518	32.4*
Size Reduction. (R)	0.030	0.058	1	0.058	3.63**
Fermentation. Time	0.010	0.000	1	0.000	0.00
Dewatering Press (P)	0.030	0.058	1	0.058	3.63**
INTERACTION					
TR	0.010	0.006			
PT	0.00	0.000			
FT	0.030	0.058		0.016	
FR	0.030	0.058	11		
PR	0.00	0.000			
PF	0.00	0.000			
FTR	0.030	0.058			
PTR	0.000	0.000			
PTF	0.000	0.000			

Table 4: Statistical Analysis of Variance Table Effect of Processing Factors on Coefficient of Friction on Steel

Source of variance	Effect	Sum of Squares	DF	Mean of Squares
Average	0.508			
Main Efffect				
Drying Temp (T)	0.00	66.59	1	66.59
Size Reduc.(R)	-0.04	0.10	1	0.10
Ferm. Time (FT)	0.00	0.00	1	0.00
Dewatering press(P)	0.00	0.00	1	0.00
INTELACTION EFFECT				
FR	0.00	0.00	1	0.00
PR	0.00	0.00	1	0.00
PF	0.00	0.00	1	0.00
TR	0.00	0.00	1	0.00
FT	0.00	0.00	1	0.00
PT	0.00	0.00	1	0.00
FTR	0.00	0.00	1	0.00
PTR	0.00	0.00	1	0.00
PTF	0.00	0.00	1	0.00
PER	0.00	0.00	1	0.00
FRTP	0.00	0.00	1	0.00

Table 5: The Result of Experimenting on Effect of Dried Fermented Cassava on Angle of Reponse.

Sample	Temp	Size Reduction	Days	Pressure (MPa)	Angle of Repose
1	50	R. Water	3	5	20.3
2	80	R. Water	3	5	20.2
3	50	H. Mill	3	5	17.9
4	80	H. Mill	3	5	18.0
5	50	R. Water	5	5	18.9
6	80	R. Water	5	5	18.9
7	50	H. Mill	5	5	18.0
8	80	H. Mill	5	5	17.9
9	50	R. Water	3	10	19.9
10	80	R. Water	3	10	20.0
11	50	H. Mill	3	10	18.0
12	80	H. Mill	3	10	18.2
13	50	R. Water	5	10	19.1
14	80	R. Water	5	10	19.0
15	50	H. Mill	5	10	17.9
16	80	H. Mill	5	10	18.3

Table 6: Statistical Analysis of Variance Table for Effect of Processing Factors on Angle of Repose.

Source of Variation	Effect	Sum of Squares	Degree of Freedom	Mean of Square	F
Average	18.750	18.722			
Main Effect					
Drying Temp. (T).	0.000	0.000	1	0.000	
Size Reduc. (R)	-1.5	144.0	1	144.000	81.81*
Dewatering Press (P)	0.000	0.00	1	0.000	
Ferm. Time (F)	-0.500	16.00	1	16.00	9.090**
INTERACTION					
TR	0.000	0.000			
PT	0.000	0.000			
FT	0.000	0.000			
FR	0.550	19.360	11	1.76	
PR	0.000	0.000			
PT	0.000	0.000			
FTR	0.000	0.000			
PTR	0.000	0.000			
PTF	0.000	0.000			
PFR	0.000	0.000			
FRTP	0.000	0.000			

* Significant 1%

** Significant at 5%.

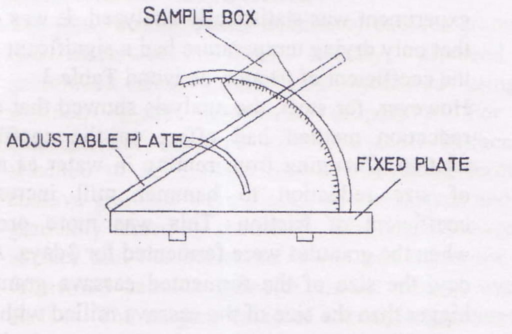

Figure 1: The inclined plane

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