Angle of Repose of Digested Oil Palm Fruit Mash and Pulp on Steel

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Abstract
The angles of repose of digested palm fruit mash and pulp on mild and stainless steel were determined in this study because of it important in the design and fabrication of palm nut-pulp separating machine proposed for total elimination of nut breakage and its associated losses in all mechanized palm fruit processing. The experimental plan was based on completely randomized design (CRD) while the data obtained were tested and compared using Analysis of variance (ANOVA). Results showed that the angle of repose of digested palm fruit mash on both mild and stainless steel is same and equal to 46.01^0 while that of digested palm fruit pulp on these two structural materials is 47.91^0. ANOVA results revealed that there are no significant differences (at $\alpha = 0.05$) in angles of repose of the test specimens obtained from the dura and tenera palm fruits and also that the values of this parameter obtained as per each test is independent of the weight of the specimen used.

Key Words: Angle of repose, mild and stainless steel, nut breakage, nut- pulp separating machine, pressing

I. INTRODUCTION

The oil palm *(Elaeis guineensis)* is one of the world's most important oil producing plants. Its fruits produce two types of oil; the palm oil which is extracted from the fruit pericarp (pulp) and palm kernel oil from its seeds (palm kernel), both of which are very important in the world trade due their wide industrial and domestic applications [1], [2] , [3], [4]. The three main varieties of the oil palm distinguished by their fruits characteristics are dura, pisifera and tenera, however, successful processing of the fruits into palm oil and kernel products is only possible with dura and tenera fruits due to shelless nature of pisifera [5]. Ref. [6] and [7], said that the extraction of palm oil and kernel from the fruits involves field and factory/house operations. The field processes include cutting ripe fruit bunches from the palm tree and transporting them to the factory/house while cooking and digestion of the fruits, squeezing of palm oil out of the digested fruit pulp and clarification/purification of the extracted palm oil constitutes the factory operations

The two variant methods of carrying out these factory operations are the traditional and mechanical methods [3]. The mechanized process with screw press as the means of palm oil extraction is the most commonly used in the modern palm fruit processing because it requires less power and capital cost for a given pressing capacity and also its palm oil extraction rate is independent of the efficiency of the sterilization and digestion processes unlike other presses/other palm oil extraction equipment [8]. However, the major problem of using screw press for palm oil extraction is nut breakage and previous efforts on total elimination of this problem caused excessive loss of palm oil to pressed fibre [4]. [5] According to [9], mechanically processed palm nuts usually contains 10 to 15% broken nuts when screw press is used for palm oil extraction at an optimal 9 to 10% palm oil loss to pressed fibre. Also, [8], indicated 9 to 22% nut breakage depending on the type of fruit being processed with 8% oil content in the pressed fibre while an average palm oil loss to fibre of 10.7% with a screw press was reported by [10]. Ref.[4] further showed that in a small scale process where the breakage was not checked to achieve 2-3% palm oil content of the pressed fibre, the bleachability and oxidation conservation of the palm oil extracted was adversely affected. Ref. [11], explained that the quality of palm oil extracted in this later process was negatively affected because some small nuts/kernels crushed during pressing released traces of palm kernel oil into the extracted palm oil and the two oils cannot be separated by simple methods.

Furthermore, absent of palm nut-pulp separation process in all the mechanized palm fruit processing method as contained the traditional technique was identified as the major cause of the nut breakage associated the use of pressing for palm oil extraction [11]. The traditional palm fruit processing separates digested palm fruit mash into nut and pulp before hand squeezing of palm oil out of the digested fruit pulp while in the mechanized system, the digested mash is subjected to pressing without removing the nuts. Thus, nut breakage during palm oil extraction is not encountered in the traditional palm fruit processing. But [4], said that all mechanized palm fruits processing machinery/equipment were developed based on the observation of the traditional technique of West Africa. Also it is only the pulp part of the fruit that contains palm oil extracted at this stage [1], [3], [4]. It was based on these facts that [11], proposed a unit operation sequence modification in the mechanized palm fruit processing to include a palm nut-pulp separating machine between the digester and press as shown in Figure 1 for total elimination of nut breakage and its other associated losses in this sector.

In order to design and develop the proposed palm nut-pulp separating machine, some engineering properties of the digested palm fruit mash (the raw material input to the proposed machine) and those of the digested pericarp (pulp) and wet palm nuts (output materials from the machine) are required.

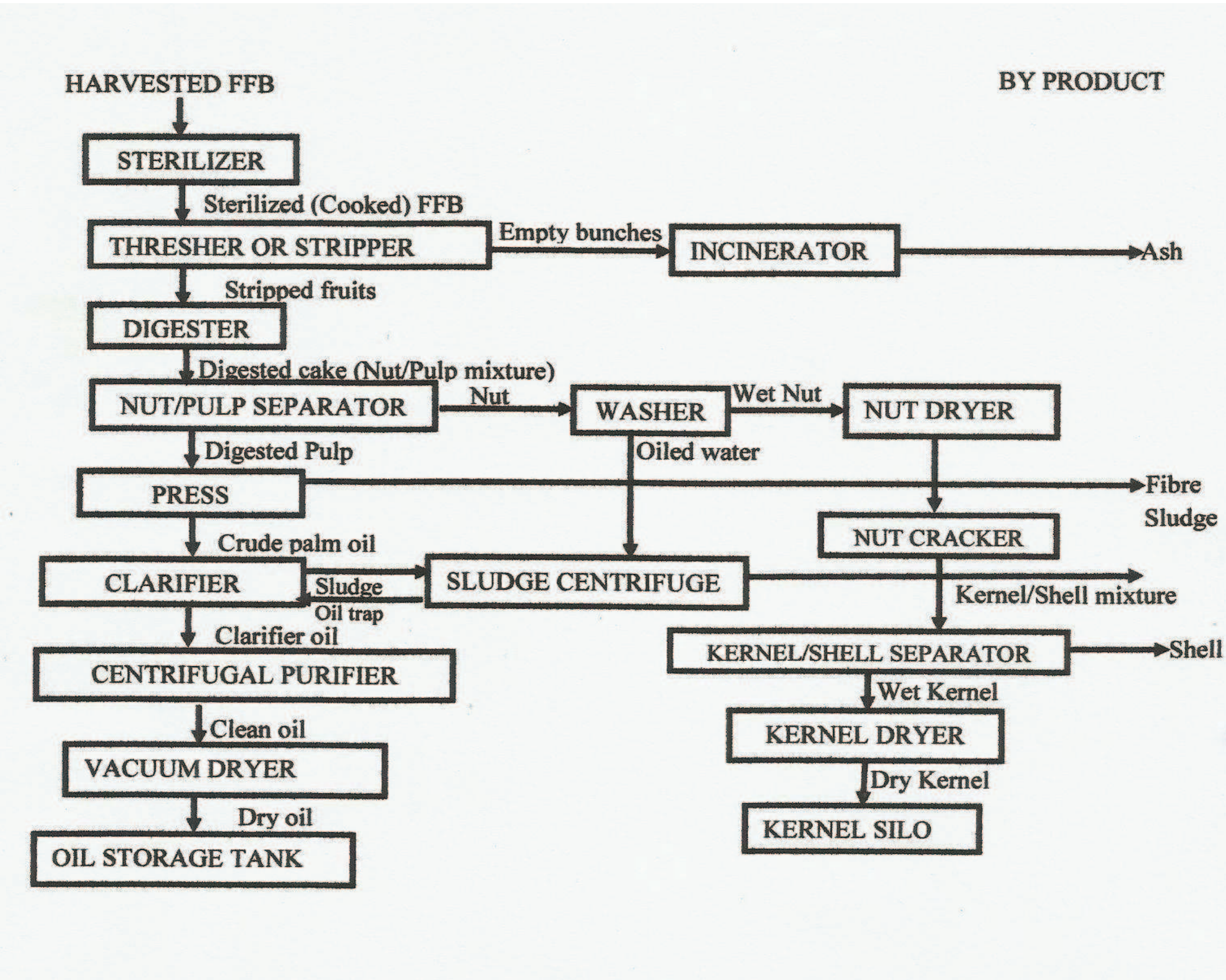

Figure 1: Flow diagram of palm oil and kernel extraction by mechanical methods with the proposed palm nut-pulp separation unit operation.

The engineering properties of these biomaterials required in the design of this machine include density, size and shape, hardness, compressive strength and angle of repose/coefficient of friction of the materials on mild and stainless steel. The values of these parameters are highly required in this proposal because engineering properties of biomaterials constitute essential data in design of machines, structures, processes and controls. Ref. [12] said that they are useful in the analysis and determination of the efficiency of machines, development of new products and equipment, and the final quality of products. According to [13], size and shape are very important in determining methods of separation and cleaning methods while density and specific gravity are used in calculating thermal diffusivity and volume/weight capacity of machine components. Mechanical properties such as hardness and compressive strength are used for predicting resistance of produce to cracking and energy required in size reduction respectively [13]. Compressive strength is also relevant in the choice of stack height to avoid damage of produce during storage. Angle of repose/coefficient of friction of materials on various structural surfaces is very important in predicting the movement of the materials in the processing equipment and pressure exerted on the walls of the equipment. A separation technique based on the coefficient of friction of a modified inclined plane is also in use for separating palm kernel and shell.

Some documented information on the measurement of some properties of digested palm fruit mash, digested pulp and palm nuts exist in some literatures. Ref. [8], reported the densities of the digested palm fruit mash, digested pulp, pressed fibre, un-pressed dura and tenera nuts from experimental measurement as 1060kg/m^3, 0.925 kg/dm^3, 1.04kg/dm^3, 781 g/dm^3 and 656 g/dm^3 respectively. Medium (average) size fibres are approximately 25mm long and 250 micron in diameter [8]. Although, engineering properties of biomaterial are dependent on factors such as species and climate of its environment, [8], further confirmed experimentally that despite the fact that the proportion of mesocarp to fruit varies widely according to fruit types, the composition of sterilized/digested mesocarp (digested pulp) is relatively constant comprising 54% palm oil, 28% water and 18% non-oil solids. In addition, [13], showed that the major, intermediate and minor diameters of dura nuts varies from 26.5 to 44mm, 21.5 to 34.5mm and 16.5 to 28mm respectively. Compression strength of dura nuts in terms of its fraction and cracking resistance has been determined as 0.2 to 3.7kN [14]. Also, other properties of the seed under compression have been investigated [12] [15] and [16]. However, despite an extensive literature search, there is no published information on the measurement of the angle of repose and coefficient of friction of digested palm fruit mash and pulp with respect to mild and stainless steel. Generally, coefficient of friction, μ of any structural surface with respect to another is related to its angle of repose, θ as follows:

$$\mu = \tan\theta \qquad (1)$$

Mild and stainless steel are among engineering materials commonly used for machine/equipment fabrication in most developing nations like Nigeria because the materials are non-toxic, easily to fabricate and machinable, not easily worn out and strong with high carrying capacity and also usually available locally at an affordable cost [17]. Thus, the cost of production and maintenance of the proposed palm nut-pulp separating machine will low if its design and fabrication is based on these steel materials. Since the angles of repose/coefficients of friction of digested palm fruit mash and pulp with respect to these two structural materials are vital parameters in the design and fabrication of the separating mechanism, feeding and discharging units of the proposed machine, it is therefore, the specific objective of this work to determine the angles of repose of digested oil palm fruit mash and digested pulp with respect to mild and stainless steels.

II. MATERIALS AND METHODS

The dura and tenera palm fruits used in this study were procured from Onyeije Oil Palm Plantation, Amawom and Abia State Small Holders Oil Palm Management Unit, Akoli-Imenyi respectively. The fruits were processed to digested fruit mash and pulp (test specimens) using small scale processing equipments at Okey Oil Mill factory, Ozuitem by Ahia Orie Ugba, Umuahia in Abia State of Nigeria. A completely randomized design (CRD) involving eight batches of fifteen experimental tests per batch was used for this investigation. The angles of repose of digested dura mash with respect to mild and stainless steels were determined in the first and second batch of the trails respectively. The third and fourth, fifth and sixth, and the seventh and eighth batches of the trials respectively explored the angles of repose of digested dura pulp with mild and stainless, tenera mash with mild and stainless, and tenera pulp with mild and stainless. In each test the emptying angle of repose between a weighed specimen (digested mash or pulp) and the structural materials (mild or stainless steel) was determined using the inclined plain procedure as described by [18]. A four sided topless and bottomless plywood box with dimensions 150mm x100mm x 40mm were filled with a weighed specimen and placed on the surface of an adjustable tilting table. Two adjustable tilting tables with one having a new mild steel plate surface while the other with a new stainless steel plate surface were used. The box was raised 2mm to allow only the specimen to be in contact with the structural surface. The structural surface with the box on its top was gradually tilted until the box just starts to slide down. The vertical distance or height of the inclined plane as the specimen is about to slide was measured in each case and recorded. Thereafter, the angle of repose, θ was computed from the data obtained as per each experimental run using Equation (2).

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

where h and l are the vertical (height) and fixed horizontal (280mm) distances of the inclined plane just before the specimen slides. The data obtained from this investigation were tested and compared using Analysis of Variance (ANOVA).

III. RESULTS AND DISCUSSION

The experimental results obtained with digested dura palm fruit mash and pulp samples are presented in Table 1 while those of the samples obtained from tenera fruits are shown in Table 2. These results (Tables 1 and 2) showed no difference between the mean values obtained for the angle of repose of digested palm fruit mash on the mild and stainless steel and also that of digested pulp on the mild and stainless steel. The analysis of variance results of the data presented in these tables showed no significant difference (at α = 0.05) in angles of repose obtained for digested palm fruit mash on the mild and stainless steel irrespective of the fruit specie from which the specimen was obtained and this is also observed in the values of this parameter for the digested pulp on both materials. Results also revealed that the values of this parameter obtained are independent of the weight of the specimen under investigation.

Table 1: Angle of Repose of Digested Dura fruit Mash and Pulp with respect to Mild and Stainless Steel

S/No.	Mass of Specimen (g)	Horizontal Distance (mm)	Digested Palm Fruit Mash				Digested Pulp			
			Mild Steel		Stainless Steel		Mild Steel		Stainless Steel	
			Vertical Distance (mm)	Angle of Repose (°)	Vertical Distance (mm)	Angle of Repose (°)	Vertical Distance (mm)	Angle of Repose (°)	Vertical Distance (mm)	Angle of Repose (°)
1	30.00	280.00	290.10	46.02	291.00	46.10	310.00	47.91	310.00	47.91
2	35.00	280.00	290.00	46.01	290.00	46.01	309.90	47.90	310.00	47.91
3	40.00	280.00	290.00	46.01	289.80	45.99	310.20	47.93	310.00	47.91
4	45.00	280.00	289.80	45.99	290.00	46.01	310.20	47.93	309.90	47.90
5	50.00	280.00	289.90	46.00	289.80	45.99	310.00	47.91	310.00	47.91
6	55.00	280.00	290.10	46.02	290.10	46.02	310.00	47.91	309.90	47.90
7	60.00	280.00	290.00	46.01	290.00	46.01	310.00	47.91	309.80	47.89
8	65.00	280.00	290.00	46.01	289.80	45.99	309.90	47.90	310.50	47.96
9	70.00	280.00	289.80	45.99	289.80	45.99	309.90	47.90	310.00	47.91
10	75.00	280.00	290.00	46.01	289.90	46.00	309.90	47.90	310.00	47.91
11	80.00	280.00	290.10	46.02	290.10	46.02	310.00	47.91	309.90	47.90
12	85.00	280.00	290.10	46.02	290.00	46.01	310.40	47.95	310.00	47.91
13	90.00	280.00	290.10	46.02	289.90	46.00	309.90	47.90	310.00	47.91
14	95.00	280.00	290.00	46.01	290.00	46.01	310.00	47.91	309.90	47.90
15	100.00	280.00	290.00	46.01	290.10	46.02	310.00	47.91	310.00	47.91
TOTAL				***690.15***		***690.17***		***718.68***		***718.64***
AVERAGE				**46.01**		**46.01**		**47.91**		**47.91**

S/No.	Mass of Specimen (g)	Horizontal Distance (mm)	Digested Palm Fruit Mash				Digested Pulp			
			Mild Steel		Stainless Steel		Mild Steel		Stainless Steel	
			Vertical Distance (mm)	Angle of Repose (^{0})	Vertical Distance (mm)	Angle of Repose (^{0})	Vertical Distance (mm)	Angle of Repose (^{0})	Vertical Distance (mm)	Angle of Repose (^{0})
1	30.00	280.00	290.00	46.01	290.10	46.02	309.90	47.90	310.00	47.91
2	35.00	280.00	289.80	45.99	290.00	46.01	310.00	47.91	310.00	47.91
3	40.00	280.00	290.00	46.01	289.80	45.99	310.00	47.91	310.50	47.95
4	45.00	280.00	289.90	46.00	290.10	46.02	310.00	47.91	310.00	47.91
5	50.00	280.00	290.10	46.02	290.10	46.02	310.00	47.91	310.00	47.91
6	55.00	280.00	291.00	46.10	289.80	45.99	309.80	47.89	309.90	47.90
7	60.00	280.00	289.80	45.99	290.00	46.01	310.00	47.91	309.90	47.90
8	65.00	280.00	289.80	45.99	290.00	46.01	309.90	47.90	310.00	47.91
9	70.00	280.00	289.80	45.99	289.80	45.99	310.00	47.91	309.90	47.90
10	75.00	280.00	290.00	46.01	290.00	46.01	309.90	47.90	309.90	47.90
11	80.00	280.00	290.10	46.02	290.00	46.01	310.00	47.91	310.00	47.91
12	85.00	280.00	289.90	46.00	291.00	46.10	310.20	47.93	310.00	47.91
13	90.00	280.00	289.80	45.99	289.80	45.99	310.00	47.91	310.00	47.91
14	95.00	280.00	289.80	45.99	290.00	46.01	310.00	47.91	310.00	47.91
15	100.00	280.00	290.10	46.02	290.00	46.01	309.90	47.90	310.10	47.92
TOTAL				***690.13***		***690.19***		***718.61***		***718.66***
AVERAGE				**46.01**		**46.01**		**47.91**		**47.91**

Table 2: Angle of Repose of Digested Tenera fruit Mash and Pulp with respect to Mild and Stainless Steel

These observations are in agreement with [8] which reported that the composition of both the digested palm fruit mash and pulp are relatively constant and independent of the fruit specie from which it was obtained. However, it is also obvious from these tables that the angle of repose of digested palm fruit mash ($\theta = 46.01^0$) on both structural materials investigated differs from that of digested pulp which is 47.91.

IV. CONCLUSION

The angle of repose of digested palm fruit mash with respect to both mild and stainless steel is 46.01^0 while that of the digested and pulp on these structural materials is 47.91^0. This study revealed that the value of this parameter is independent of the oil palm fruit specie (dura or tenera) from which the specimens were obtained but depends on the structural materials (mild and stainless steel) and the nature of the specimen (digested mash or pulp).

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