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Comparative Studies of Palm Oil Separation Techniques For Improved Oil Recovery

B.O. Abikoye, S.R Ogblechi, T.O Okoronkwo, A.O obande , E. Ataga

Engineering Division, Nigerian Institute for Oil Palm Research (NIFOR), Benin City, Nigeria

Corresponding author email: benabikoye@yahoo.com

ABSTRACT: Palm oil milling by wet process makes use of large quantity of water and consequently generates larger amount of waste water. More often than none, the quantity of useful oil entrapped within the discharging sludge become unbearable and cumulatively amounts to a huge loss to mill owners/operators.A comparative study was carried out on the vertical and horizontal settling behaviour of crude palm oil at the Engineering Research Division of the Nigerian Institute for Oil palm Research (NIFOR). This study is aimed at increasing the amount of useful oil recovered from the sludge and increase palm oil yield per tonnage of fresh fruit bunch. The feed compositions were determined by centrifugal method. Experimental data were taken on the settling behaviour of the oil- sludge mixture, the experimental data were factor out and reduced to manageable size by the spearman's factor solution and then validated statistically with the analysis of variance (ANOVA). 0.94 representing 94% of the variance was accounted for as R^2 in the vertical settling experiments while 0.80 representing 80% of the variance was accounted for as R^2 in the horizontal settling experiments.The study result provides useful design model for predicting the performance of crude palm oil tanks and it is a tool for palm oil production management.
Keywords: Palm oil mill; Production management; Settling tank; Settling time.

INTRODUCTION

Oil palm is one of Nigerians most important economic crops, providing raw materials for related agro-based industries and employment for the teaming population most especially in the rural areas. Palm oil milling by the wet process accounts for not less than 90% of oil extracting activities in Nigeria [1], this may not be totally different in many other parts of the world where palm oil is produced. A study conducted in 2000 by a group of scientists in Thailand shows that about 75-78% of the global palm oil extracting capacity is by wet process [2].

The wet process makes use of large amount of process water and requires an efficient settling technique and / technology to recover reasonable portion of useful oil from the sludge. From fruit sterilization at a pressure of 2-3bar to fruit digestion with hot water at about 80 ^{0}C, crude palm oil extraction, separation as well as the recovery of palm oil in clarification systems, One can hardly do without enough process water. In the upstream, water is added to improve the flow ability of the process stream and the extraction efficiency while in the down stream, it is used to enhance the fluidity of the extracted liquid which is normally in a 3- phase mixture (oil, water and solids) in series of decantation [3, 4].

Palm oil separation generally adopts a vertical or horizontal settling tank. Depending on the preferred method, variables to be considered include fluid flow rate, feed composition, settling volume, retention time and settling temperature. In any case, the amount of residual oil is mostly used to examine the efficiency of the settling method.

As a way of improving on the design and increase the amount of oil recovered from the sludge, a comparative study was initiated on the two major types of palm oil settling techniques. The study was conducted using the NIFOR 2 tonne per hour mill.

This paper presents the statistical analysis of some of the experimental data obtained. Analysis of the experimental results provides useful design information for minimizing process water in palm oil mills

MATERIALS AND METHODS

The settling behaviour of palm oil was studied in both horizontal and vertical settling tanks. For the series of experiments, palm oil mixtures were obtained directly from the processing mill and the composition of each of the samples were determined before any further settling observations.

Brief Description of Equipment

The NIFOR Large Clarifier was used to generate data for the vertical settling experiment while a small horizontal settling tank (settling based on residence time) was used for the horizontal settling experiment.
The vertical settling tank is a steam jacketed drum curved towards the bottom to form a conical edge. The light phase of hot crude palm oil flows slowly upward in the tank and the heavy materials settle down the tank by gravity to form a distinct layer.

The horizontal settling tank is a series of 2 interconnected rectangular tanks through which the palm oil mixture flows gently from one end of the tank partition to the other. Settling takes place in the course of the flow and palm oil is collected through an adjustable opening at the top end of each compartment of the tank.

METHODOLOGY

40 litres of crude palm oil were collected from the mill. The composition of the feed were determined by the centrifugal method and then fed into each of the settling tanks already charged with known quantity of hot water.

For the vertical tank experiment, the tank is stirred till homogeneity. Interface of sludge and the liquid palm oil is observed with time. This interface gradually precedes downward the tank and the difference in the height is calculated for every 50ml of liquid palm oil recovered from the tank. The time taken to recover the 50ml portion is noted and recorded until the interface completely disappears.

In the horizontal settling tank experiment, crude palm oil is fed into the tank through an opening at the receiving end of the tank and gradually move through a series inter-connected rectangular tanks. Heat from the hot water flowing round the tank provides the required temperature for settling and it is maintained slightly below boiling. Separated oil is recovered through the adjustable opening at the upper part of the tank and the sludge is recovered below the tank through a valve.

Volumetric compositions of the feed were determined by tube centrifuge, calculated by weight composition and the percentage of oil in the sludge determined by partition gravimetric method.

The experiments proceed for several milling operations and different species of oil palm. The spearman's factor solution method was used to cluster the large set of data obtained to 20 and 30 samples for vertical and horizontal settling respectively. The analysis of variance was carried out from which the R^2 and adjusted R^2 were estimated.

The hypothesis is checked by comparing the calculated F with the critical value using F statistics table. The source of variability is identified by ANOVA approach. The ANOVA test procedure involves the term "sum of squares" which measures the variability due to the level of significance and the estimated errors.

$$R^2 = 1 - \frac{SSE}{SST} \quad \text{………. …………..} \quad (1)$$

$$R^2 \text{(adjusted)} = 1 - [n-1/n-p] \quad (1- R^2) \quad \text{…………………….} \quad (2)$$

Table 1. ANOVA for the vertical settling

Variability`	DOF	SS	MS	F
Regression	J-1, 4	121.48	30.37	58.52
Residual	n_T-J, 15	7.79	0.519	
Total	n_T-1, 19	129.27		

R^2 = 0.94 and R^2 (adjusted) = 0.933

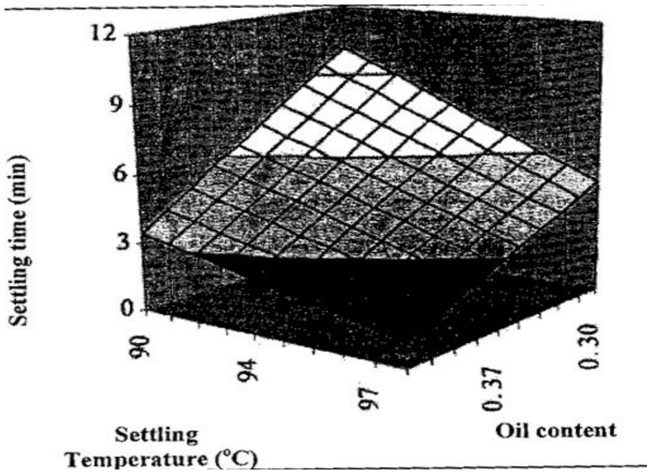

Figure 1. 3D Response Plot for the vertical settling tank (Temperature Controlling)

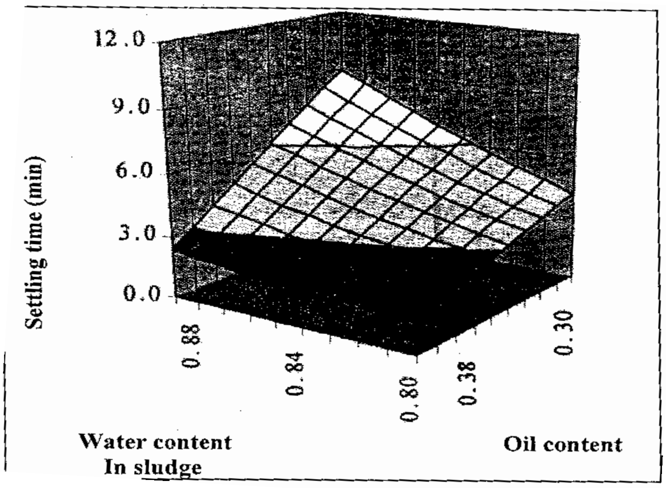

Figure 2. 3D Response Plot for the Vertical settling tank (Water in sludge controlling)

Table 2. ANOVA for the horizontal settling

Variability`	DOF	SS	MS	F
Regression	J-1, 2	0.0216	0.01080	53.47
Residual	n_T -J, 27	0.0055	0.000202	
Total	n_T-1, 29	0.0271		

R^2 = 0.80 and R^2 (adjusted) = 0.79

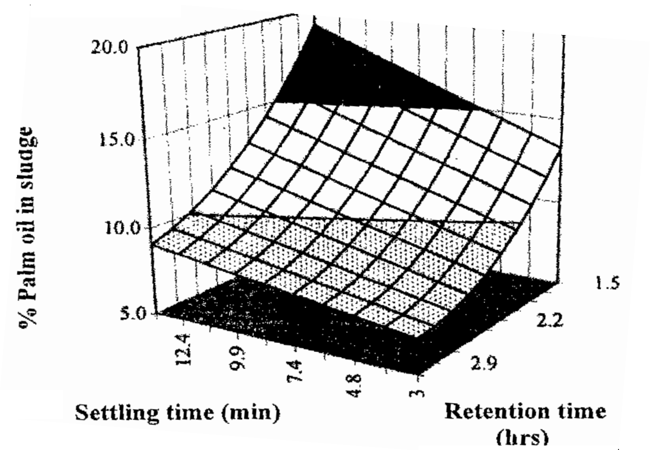

Figure 3. 3D Response Plot for the Horizontal Settling tank

DISCUSSIONS

Palm oil settling is a physical separation process of 3 phases in mixture. The distinct interface of sludge sediment and the palm oil is caused by the force of gravity and the time taken by distinct interface to disappear into 1 single phase is described as the settling time. Observation shows a gradual increase in the rate of separation as heating progresses. This established an earlier claim by Hulston et al (2003) that temperature is a very important parameter influencing the settling of palm oil during oil clarification.

Table 1 presents the ANOVA result for the batch vertical settling tank. From the table, the sum of square for the settling time model of 4 degree of freedom is 121.48, F_o is 58.52 and the critical value $F_{0.05,\ 4,19}$ is 2.90.

Since F_o is greater than $F_{0.05,\ 4,19,}$ the null hypothesis is rejected and it can be deduced that at least one of the independent variables is a contributing factor to the regression thus a significant statistical dependency exists between them.

In the horizontal settling tank, the separation mechanism involves the feed flow from the receiving end of the tank to the other end and therefore, the stream flow rate and the settling volume are the major controlling factors in the separation of oil from sludge. Though the feed composition and process temperature can not be ruled out but retention time (a combined function of the flow rate and settling volume) is the settling rate determining factor.

Mathematically, Rt = V/Q.

Where V is the settling volume in m^3, Q is the feed flow rate in m^3/hour and Rt represents the retention.

The regression sum of squares with 2 degree of freedom for the vertical settling gave 0.0216, F_o = 53.47 and the critical value $F_{0.05,\ 2,29}$ is 3.33.

Since F_o is greater than $F_{0.05,\ 2,29}$, the null hypothesis is rejected and Rt is said to be significant in determining the amount of oil residue in the sludge.

The statistical analysis for R^2 and R^2 adjusted gives 0.94, 0.933 and 0.80, 0.79 for the vertical and horizontal settling tank respectively. The implication of this is that 94% of the variance is accounted for in the vertical settling model and 80% of the variance is accounted for in the horizontal settling model.

The values for the each adjusted R^2 in the vertical and horizontal model is close to their corresponding values of R^2 and this shows that all terms and variables considered are statistically significant.

The 3D response plots for the vertical settling tank (figure 2 and 3) that the increase in settling temperature and the decrease in water content of the sludge resulted in a reduced settling time. This is enhanced by the reduction of water usage in the upstream processes.

Figure 4 shows the 3D response surface plot for the horizontal settling tank. The figure shows a low percentage of oil residues in the sludge. This is enhanced by the decrease in the settling and the increase in the retention time.

CONCLUSION

The work shows a statistical description of horizontal and vertical settling tanks.

The result obtained is a useful design model for predicting the performance of crude palm oil settling tanks in order to achieve low oil residue in the sludge. The model is also a useful tool in setting a thin line between mill capacity and productivity.

Since Rt = V/Q and every palm oil processing mills operates a fixed settling volume, it may be logical to conclude that the retention time in palm oil settling depends absolutely on the feed flow rate and subsequently on the mill's production capacity. One would have been tempted to say that a maximum settling efficiency is achievable at the expense of productivity limitation (i.e. reducing Q). However, Productivity and separation efficiency are both cost factors for the mills and therefore, mill owners/operators need to perform a real time optimization and locate the optimum mid point between these two important cost factors.

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