PALM KERNEL OIL EXPRESSION BY UNIAXIAL COMPRESSION

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ABSTRACT

Palm kernel oil yield was found to be dependent on operative processing variables including: heating temperature, applied pressure and particle size to which ground palm kernel samples of fine and coarse particle sizes were subjected to using a Piston-cylinder Rig under an instrumented hydraulic uniaxial compression. The effects of heating temperature and applied pressure on the oil yield was investigated at heating temperatures of 70, 90, 110, and 130 ^{0}C and applied pressures of 6, 9, 12 and 15 MPa. The oil expressed from each temperature level at optimum applied pressure of 15 MPa was subjected to laboratory analysis using AOAC 1991 recommended method at the analytical and quality control laboratory of the Global Soaps and Detergents Industries, Ilorin, Nigeria. From the results, the highest palm kernel oil yield obtained was 32.15 % at optimum conditions of 15 MPa applied pressure for 10 minutes and 110 °C heating temperature for 30 minutes on samples of 4.5 % moisture content dry basis. This yield corresponds to an expression efficiency of 71.8 % of the total palm kernel oil content. Increase in oil yield was recorded at corresponding increase in heating temperature and applied pressure, but the oil yield begins to drop after an optimum heating temperature of 110 °C was attained. Oil yield from fine particle size of palm kernel was discovered to be significantly different from that obtained from coarse particle size at 5 % level of confidence.

The result of the physico-chemical characteristics of the palm kernel oil at temperature of between 70 - 130 ^{0}C are: Free fatty acid 4.02 - 4.63 %; Acid value 11.29-12.0 mgKOH/g; rancidity index 2.4R.21Y–1.9R.10Y; saponification value 246.57-243.80mgKOH/g; viscosity 140 – 60cps and specific gravity 0.908-0.894. The result indicates that the quality of the expressed oil decreases as the heating temperature increases.

KEYWORDS: Palm kernel oil, oil yield, expression efficiency, hydraulic uniaxial compression.

1. INTRODUCTION

The increase in the world's population has no doubt increased the demand for fats and oils obtained from oil bearing crops. Oil-bearing crops are classified into three, namely: *Oil seeds and beans* (e.g. Cotton, Rape, Mustard-seed, Beniseed, Sesame, Sunflower, etc); *nuts* (e.g. Coconut, Copra, groundnut, Shea nut, palm kernel, etc); and mesocarps or fruits (e.g. Oil palm, Avocado, Olive, etc). About 90% of the oil and products from it are used for food applications, while about 10% goes into non food applications, (Pantzaris, 2000).

The Oil Palm, which gives both Palm Oil (PO) and Palm Kernel Oil (PKO), is *Elaeis guineensis* (Hartley, 1988). The Palm Oil (PO), which is reddish in colour, is obtained from the Orange colour mesocarp, while the PKO is obtained from the hard-liquefied cell within the nut, called the kernel.

According to Praven, (1997) and Breadson, (1983), modern Processing of Oil bearing crops (seeds or nuts) into edible or industrial oil is practiced using different methods, which may be categorized into three. One is the solvent extraction method in which a solvent, when brought in contact with the preconditioned oil seed or nut, dissolves the oil present in the oil bearing material and the separated mixture is later heated to evaporate the solvent and obtain the oil. Mechanical oil expression is the second method. In this process, the preconditioned oil seed or nut is passed through a screw press, a hydraulic press or a ram press, where a combination of high temperature and pressure is used to crush the oil bearing material to release the oil. The third method is the wet processing in which the oil bearing material is boiled in water leading to a partial separation of oil (clarification).

The effect of particle size, heating temperature, heating time, applied pressure and duration of pressing on the yield and quality of mechanically expressed groundnut oil were investigated by Adeeko and Ajibola (1989). Result showed that oil yields from coarsely ground groundnut samples were higher than those from finely ground samples but the free fatty acid values were lower. Increasing the temperature did not improve the oil yield and the rate of oil expression was increased by an increase in temperature, time of heating, and particle size. An increase in the heating temperature and heating time increased the free fatty acid value, peroxide value and the colour intensity of the oil expressed. Olaniyan (2010) investigated the effects of some process conditions like nature of bean, heating temperature and pressing time on the yield and quality of oil mechanically expressed from castor bean using a piston-cylinder rig in association with California Bearing Ratio Universal Testing Machine (CBR – UTM). The Results showed that process conditions and their interactions were significant on oil yield at 0.05 % level of significance. However, only the pressing time was significant on the extraction pressure. Oil yield increased with increased heating temperature and pressing time for the crushed bean, shelled bean and unshelled bean.

Bamigboye and Adejumo (2011) carried out investigation on the effects of the processing parameters of Roselle Seed on its oil yield. The seeds were ground and classified into two particle sizes (fine and coarse). The samples were conditioned by adding calculated amount of distilled water to different moisture levels from the initial moisture levels of 4.4 % and 5.14 % respectively. The samples were heated at different temperatures of 80, 90,100 and 110 °C over a period of 15, 20, 25 and 30 minutes, expressed at 15, 22.5, 30 and 37.5 MPa using hydraulic oil extractor for 10, 20, 30 and 40 minutes. The result of the investigations showed that oil yield increases by 5 % - 6 % with an increase in the processing parameters of pressure up to 30 MPa, temperature of 100 °C and decreased beyond these points. Finally ground samples were found to have a higher yield than coarsely ground samples at the different processing parameters. They concluded by affirming that processing parameters affect the oil yield from Roselle Seeds.

Not much can be found in the literature on studies undertaken on processing factors as related to oil yield from ground palm kernel of Dura variety. This prompted the present work to study the effects of some processing parameters on palm kernel oil expression.

2. EXPERIMENTAL PROCEDURE

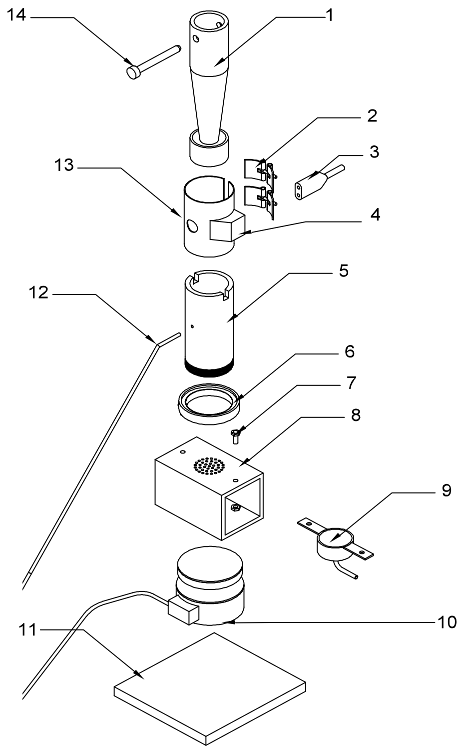
All experimental investigations were carried in the Engineering Materials Testing laboratory of the Engineering and Scientific Services (ESS) department of the National Centre for Agricultural Mechanization (NCAM), Ilorin, Nigeria. The room temperature of the laboratory throughout the duration of the experimental works was averagely 30 ^{0}C.

2.1 Material Preparation

Palm Kernel (Dura Variety) used in this experiment was obtained from the Nigerian Institute for Oil Palm Research (NIFOR), Benin city, Nigeria. Moisture content of the palm kernel at the point of procurement was determined and found to be 11.5 %. The kernels were further dried to 4.5% moisture content using sun drying method. The kernels were cleaned to remove stones and other foreign materials; after which they were firstly crushed using a hammer mill, and later the crushed meal was further reduced using an attrition mill as reported by Olaniyan, (2006). They were later packed into air tight containers and stored in the laboratory.

2.2 Experimental Machines and Instrumentation

Oil expression process normally involves the application of compressive force on the oil seed flakes enclosed in a suitable retaining envelope.



14 Stod
13 Heater band
12 Thermocouple
11 Base plate
10 Load cell with data cable
9 Oil collector
8 Supporting plat form
7 8mm bolt
6 Threaded ring
5 Press cage cylinder
4 Heater band plug port
3 Plug (from AC orDC means)
2 Heater band clip
1 Compression piston

Fig. 1: Exploded view of the Model laboratory Mechanical Oil Expression Rig

Laboratory mechanical oil expressing piston-cylinder rig was modified and fabricated, and used for this investigation (see Fig. 1).

The mechanical oil expression rig, which is similar to the one used by Olaniyan (2006) Mrema 1979 (and reported by Mrema and McNutty 1980, 1984 and 1985 on mechanical expression of oil from rape seed, cashew and Shea butter) is made up of three major components: the compression piston, the press cage cylinder and the supporting platform (Olaniyan 2006). A 600 W electric band heater was installed round the press cage cylinder to serve as a heating device for the expression process. The rig was adequately instrumented with a temperature controller to control the expression temperature, while the pressure for oil expression was obtained from the hydraulic press (made in Denmark Stenhous A/S hydraulic press with model number; 52773703 of 15 tons capacity and actuated using a lever) via the instrumentation system. The temperature controlling exercise was achieved with thermocouple connected to an Electronic Temperature Controller (Model JTC-902), which was designed and manufactured in Japan. Heat sensing was achieved by inserting the thermocouple probe into the oil seed sample through a hole on the press cylinder. A complete assembly of the Hydraulic press, the mechanical oil expression rig and the instrumentation system used throughout for the experimental investigation is as shown in Figure 2.

2.3 Experimental Investigation Procedure

2.3.1 Analytical Procedure

The oil content of ground palm kernel was determined using Soxhlet extraction apparatus in the quality control laboratory of Global Soap and Detergent, Ilorin, Nigeria. This is in accordance with the Association of Analytical Chemists (AOAC) direct gravimetric method of Soxhlet extraction.

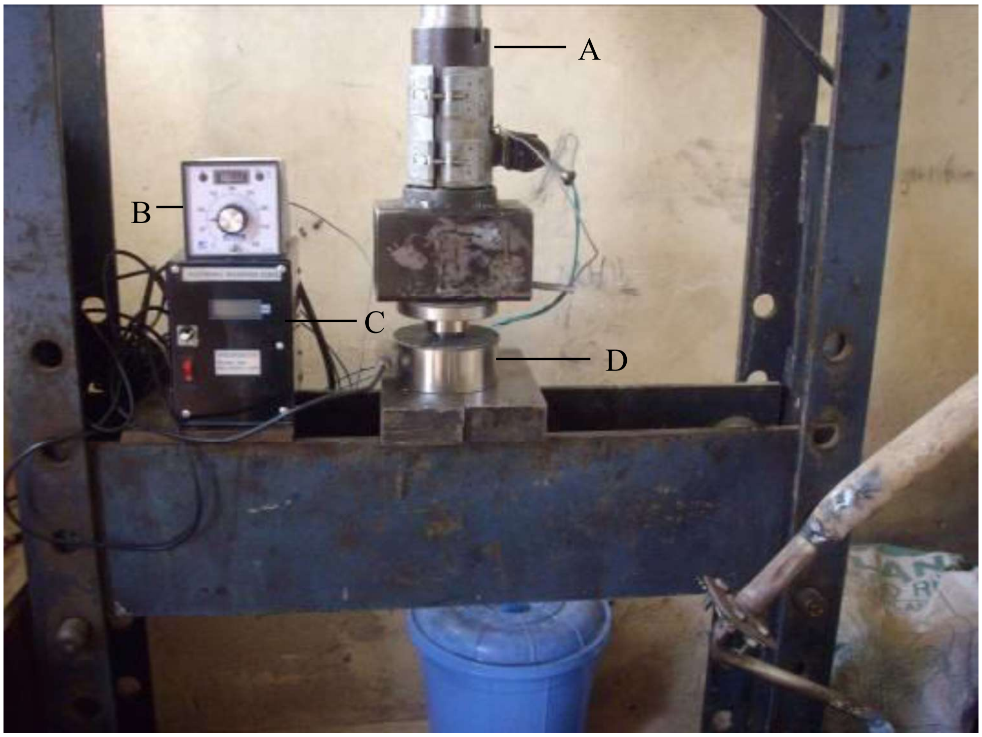


Fig. 2: Complete Assembly of the Force Measuring Device, the Mechanical Oil Expression Rig with the Temperature Controller on Hydraulic Press.

Legend
A Mechanical Oil Expression Rig
B Temperature Controller
C Amplifier with display Unit(Force Measuring Device)
D Load Cell

Likewise the physic-chemical characteristics of the expressed oil at the various heating temperature was determined using the American Oil Chemists Society (AOCS) method. Particle size analysis was carried out using a set of laboratory Endocotts Test Sieves and Shaker (model SW19 3BR England) available in the Laboratory of the Soil and Water Management Engineering Department of NCAM. Particle size analysis was done in accordance with ASAE (1989) Standard S319. In line with Adeeko and Ajibola (1990), samples that passed through the 5.6mm sieve but retained on the 2.36mm sieve were classified as coarse, while samples that passed through 2.36mm sieve but retained on the 0.6mm sieve were classified as fine. Moisture content of the sample was determined by oven drying 100g of ground sample at 130 ^{0}C for 6 hours; as recommended for oil seeds by Young et al (1982) and used by Tunde-Akintunde et al (2001).

2.3.2 Heating Sample

Heating of the sample (milled palm kernel) was achieved by weighing 200g of the sample in line with Olaniyan (2006), and transfer of the weighed sample into the press cage already encircled with the temperature controlled heater band (see Fig. 3). The samples in the press cage where heated to temperatures of 70 ^{0}C, 90 ^{0}C, 110^{0}C and 130 ^{0}C respectively for 30 minutes before expression begins. The lower limit of 70 ^{0}C and upper limits of 130 ^{0}C heating temperature was selected based on preliminary laboratory investigations, which revealed that heating milled palm kernel sample below 70 ^{0}C did not give good oil yield during expression; while heating above 130 ^{0}C results in excessive burning and darkening of the oil.

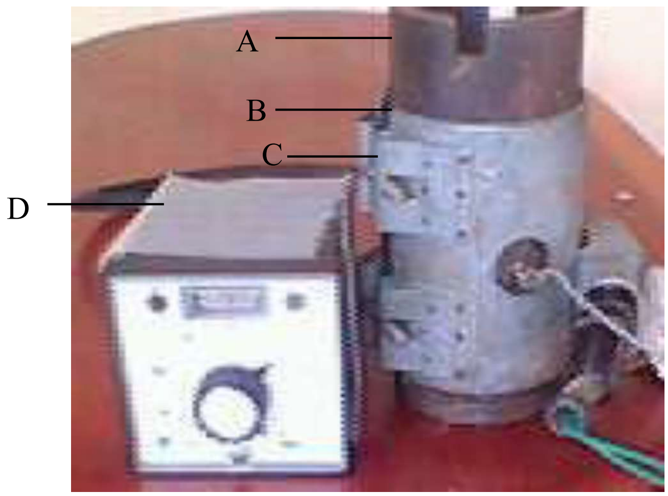


Fig. 3: Assembly of the heating system
Key: A= press cage cylinder, B=heater band, C=thermocouple, D=temperature controller

Also, the heating time of 30 minutes used in this study was chosen based on preliminary investigations and also on the fact that the period allows for temperature uniformity and equilibration of the oil seed cake as reported by Hamzat and Clarke (1993).

2.3.3 Sequence of Mechanical Oil Expression

The complete assembly of the hydraulic press, the mechanical oil expression rig with the temperature regulator, and the compressive force measuring device used in this experiment is as shown in figure 2.3. Before coupling the mechanical oil expression rig, a stainless steel wire mesh was placed at the bottom of the cylinder guide in order to cover the drainage area and at the same time serve as a filter during the oil expression process.

After the coupling, a sample of 200g weight of milled palm kernel was poured into the press cage cylinder. The sample was then heated for 30 minutes at heating temperature of 70^{0}C. Using the actuating lever of the hydraulic press, the compression piston was moved down to touch the sample and pre-compact it to a height of 70 mm (Olaniyan, 2006) inside the press cage cylinder. After the pre-compaction, the sample was further compressed by the hydraulic press via the compression piston at pressures of 6.0 MPa, for 10 minutes. The oil expressed drains into the oil collector and was collected through the outlet pipe.

On the expiration of the pressing time, the compression piston was lifted above the press cage using the actuating lever of the hydraulic press. The press cage cylinder was then unscrewed and the residual cake was extruded and weighed using a precision electronic weighing balance 1kg (0.005g) BC-Series, Manufactured by ORMA, Germany. The same procedure was followed to carry out the experiment for three other heating temperature levels of 90 ^{0}C, 110 ^{0}C, and 130 ^{0}C at 9.0, 12.0, and 15.0 MPa respectively.

2.3.4 Determination of Physical and Chemical Characteristics of Expressed Oil at Different Temperatures

The physical and chemical properties of the expressed oil determine the quality of the oil. The physical and chemical analyses of each sample of oil expressed at heating temperatures of 70 °C, 90 °C, 110 °C, and 130 °C were carried out using the AOAC (1991) recommended method at the Analytical and Quality Control Laboratory of the Global Soaps and Detergents Industries Limited, Asa Dam Road, Ilorin, Nigeria. The physical and chemical properties of the expressed oil determined are: Free fatty acid, Acid value, rancidity index, Saponification value, viscosity and specific ravity.

3. RESULTS AND DISCUSSION

3.1 Effects of Heating Temperature on Oil Yield

Table 1 is the summary of the result obtained for oil yield, at the various process conditions, while table 2 is the summary of ANOVA showing the effect of the process conditions on oil yield during mechanical expression of oil from palm kernel under uniaxial loading. From the ANOVA table, it can be observed that the process conditions (that is heating temperature and applied pressure) and their interactions had significant effect on oil yield, at 1% level of significance for the fine and coarse particle sizes respectively. Hence, the hypothesis of equality of mean treatment effect is rejected, and it can be implied that at least one of the mean treatment effect is significantly different from the others. In order to determine the differences in the mean treatment effect of heating temperature on oil yield for both particle sizes, New Duncan's Multiple Range Test (NDMRT) was carried out. The result of the comparison among the four levels of heating temperature for each of the particle size is presented in table 3.3. Table 3.3 revealed that at any particular heating temperature for each of the particle size, the observed means of oil yield are significantly different from each other. The implication is that, temperature at 70 ˚C does not have the same treatment effect on oil yield as temperature at 90 ˚C and vice versa. The table has also shown that for each particle size, the highest mean value of oil yield occurred at heating temperature of 110 ˚C, while heating temperature of 70 ˚C gave the lowest mean value of oil yield. The low oil yield recorded from samples heated at 70 ˚C could be attributed to insufficient heat treatment of the samples during the heating process. This suggest that heating temperature of 70 ˚C was inadequate for enough protein coagulation, breakdown of oil cells, reduction of moisture content to an optimum level and reduction of viscosity that allows for free flow of expressed oil.

Table 1: Summary of the Result of Effect of Process Conditions on Oil yield

Parameter			Pressure (MPa)			
	Temperature (°C)	Particle size	6	9	12	15
Oil Yield (%)	70	Fine	7.27	13.25	17.7	22.90
		Coarse	1.41	2.20	7.02	7.79
	90	Fine	8.37	9.18	8.6	13.30
		Coarse	1.78	3.93	2.1	2.19
	110	Fine	9.18	8.60	13.3	17.10
		Coarse	3.93	2.10	2.19	3.72
	130	Fine	8.60	13.3	17.1	18.70
		Coarse	2.10	2.19	3.72	9.43

Table 2: Summary of Analysis of Variance (ANOVA) of the Effects of Temperature, Pressure and Particle Size on Oil Yield

Parameter	Particle Size	Source of Variation	df	Ss	Ms	F_{cal}	Prob.

		Temperature(A)	3	278.864	92.955	118.388	0.001
		Pressure(B)	3	2692.530	897.510	1143	0.001
		AxB	9	90.643	10.071	12.827	0.001
		Error	32	25.125	0.785		
Oil yield	Fine	Total	47	3087.162			
		Temperature(A)	3	227.346	75.782	168.868	0.001
		Pressure(B)	3	598.956	199.652	444.892	0.001
		AxB	9	64.139	7.127	15.880	0.001
		Error	32	14.360	0.449		
	Coarse	Total	47	904.801			
		Temperature(A)	3	1522.290	507.430	56.207	0.001
		Pressure(B)	3	9246.183	3082.061	341.395	0.001
		AxB	9	625.671	69.519	7.701	0.001
		Error	32	288.891	9.028		

Table 3: Temperature and Pressure comparison on Oil Yield using New Duncan Multiple Range Test (NDMRT)

Particle Size	Temperature	Oil yield (%)	Pressure	Oil yield (%)
Fine	70	15.26^{a}	6	8.36^{a}
	90	18.20^{b}	9	16.63^{b}
	110	21.68^{c}	12	21.38^{c}
	130	20.23^{d}	15	28.99^{d}
Coarse	70	4.61^{a}	6	2.30^{a}
	90	5.83^{b}	9	5.65^{b}
	110	10.32^{c}	12	9.09^{c}
	130	7.95^{d}	15	11.67^{d}

Means with the same letters are not significantly different at $p \leq 0.05$ using the DNMRT

A critical look at table 1 and 3 reveals that for each of the particle size, at higher levels of applied pressure (12.0MPa and 15.0MPA) oil yield increased sharply with an increase in heating temperature from 70 ˚C to 90 ˚C, while further increase in the heating temperature beyond 110 ˚C to 130 ˚C caused a decrease in oil yield. This trend of relationship between oil yield and heating temperature is in agreement with Akinoso et al (2006), Tunder-Akintunde et al (2001), Tunde – Akintunde (2000), Adeeko and Ajibola (1989), and other researchers that had worked in oil expression too numerous to mention. They all affirmed that increase in heating temperature beyond an optimum value will definitely reduce oil yield in mechanical expression process.

The early increase in oil yield from both particle sizes due to increase in heating temperature from 70 ˚C to 90 ˚C in this study, was not far from the breaking of oil cells and the coagulation of protein, which resulted to decrease in oil viscosity and moisture content, because of the heat on the ground palm kernel samples. This heating, process had been reported by Olaniyan (2006), Ajibola *et al* 1990, Ajibola (1989) and Adeeko and Ajibola (1989) among others, to have had substantial increase in oil yield.

On the other hand, the decrease in oil yield at heating temperatures beyond 110 ˚C might be attributed to case hardening resulting from significant moisture loss from the ground palm kernel samples at higher temperatures from 110 ˚C to 130 ˚C.

3.2 Effects of Applied Pressure on Oil Yield

In order to determine the differences in the treatment effect of applied pressure that contributed more to the changes in the oil yield, New Duncan Multiple Range Test (NDMRT) was employed and the result of the comparison is as presented in Table 3.

From Table 3, the mean value of oil yield was highest at 15.0 MPa applied pressure and the lowest mean value of oil yield was at 6.0 MPa for both the fine and coarse particle sizes. The table also shows that there were significant differences between the values of oil yield at all the levels of applied pressure. The table suggests that oil yield from each of the particle sizes increased rapidly with increasing applied pressure from 6.0 MPa to 12.0 MPa compared with increase in oil yield as a result of increasing applied pressure from 12.0 MPa to 15.0 MPa.

This increase in oil yield as the applied pressure increases for both fine and coarse particle sizes may be attributed to the shearing of oil capillaries during the application of pressure in the expression process. On the other hand, the reduction in the increase in oil yield may be as a result of sealing of reasonable number of oil capillaries as the applied pressure was increased from 12.0 MPa to 15.0MPa. This observation is in agreement with the observation of Olaniyan (2006), Tunde Akintunde *et al* (2001), Ajibola *et al* (1998) and Faborode and Favier (1997). They ascertained that increasing the applied pressure beyond an optimum value will eventually seal the oil capillaries and consequently affect the oil yield.

The velocity of flow of the oil from the oil capillaries to the inter-particle voids and finally through the retaining envelop to the oil collecting pan, can also be used to explain the effect of pressure on oil yield from palm kernel during mechanical oil expression under uniaxial loading. Applied pressure of 6.0 MPa may not have been sufficient to result to free flow of oil through the inter-particle void of the ground palm kernel samples, which implies that the rate of flow of oil will be slow, thereby resulting to low oil yield at this pressure. Meanwhile, higher oil yield was obtained at the applied pressure of 12.0 MPa and 15.0 MPa due to greater forces, which increased the rate of free flow of expelled oil through the oil capillaries and out of the inter-particle voids.

3.3 The Effect of Particle Size on Oil Yield

The independent t-test was used to compare the means of fine and coarse particle sizes. The result is shown in table 4a and 4b.

Table 4a: Group Statistics Showing the Effect of Particle Size on Oil Yield

Parameter	Particle size	N	Mean	Std Deviation	Std Error Means
Oil Yield	Fine	48	18.8450	8.10458	1.16980
	Coarse	48	7.1779	4.38760	0.63330

Table 4b: Independent T-tests showing the Effect of Particle size Oil Yield

Parameter	Size	t-test for equality of means				
		T	Df	Sig. (2 tailed)	Mean Diff.	Std Error Difference
Oil Yield	Fine	8.771	94	0.001	11.66	1.33
	Coarse	8.771	72.37	0.001	11.66	1.33

From tables 4a and 4b, the mean of oil yield from fine particle sizes is significantly higher than that of coarse particle sizes at 1% level of significance. The t- statistics confirms that the differences observed in the mean values of oil yield between the fine and coarse particle sizes was not due to random occurrence alone. This significant difference in the oil yield from fine and coarse particle sizes is also evident in table 3.3 as seen earlier.

More oils obtained from fine particle sizes as compared to coarse particles sizes can be attributed to the weakening of more oil cell walls during size reduction. The weakened (or broken) oil cell-walls readily expel oil on the application of little pressure. Also, size reduction exposed a greater area of oil bearing cell walls to heat (during heat treatment) and pressure application.

4. CONCLUSION

From this study, the effect of heating temperature, applied pressure and particle size on oil yield, during mechanical expression of oil from palm kernel under uniaxial compressive loading was revealed. The following conclusions are drawn:

(i) Increase in heating temperature from 70 °C to 110 °C irrespective of the applied pressure, results to a corresponding increase in the oil yield from the fine and coarse particle size, but further increase in heating temperature from 110 °C to 130 °C results in decrease in the oil yield from both particle sizes.
(ii) Oil yield increase as the applied pressure increases from 6 MPa to 15 MPa at any heating temperature for the fine and coarse particle size respectively. The highest oil yield was recorded at applied pressure of 15 MPa while the minimum was at 6 MPa.
(iii) In order to maximize oil yield, the process conditions (i.e. heating temperature and applied pressure must be properly controlled during the mechanical oil expression process.
(iv) After an optimum temperature of 110 °C, there will be a reduction in the oil yield of palm kernel oil mechanically expressed from fine and coarse particle size of palm kernel seed.
(v) Oil yield from fine particle size are higher and significantly different from that obtained from the coarse particle size.
(vi) Physico-chemical characteristics analysis of the expressed oil showed that the quality of oil obtained reduces to a large extent as the heating temperature increases from 70 °C to 130 °C.

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