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Effect of expression conditions on the yield of Dika Nut (*Irvingia Gabonesis*) oil under uniaxial compression

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Abstract

Efficient expression of Dika nut oil from the kernel is required for its subsequent use in producing comparatively cheap lubricant. Various factors responsible for proper oil expression include particle size, moisture content, heating temperature, heating time, pressing pressure and pressing time. Sundried Dika kernel ground to two particle sizes (fine: ≤ 1.4 mm and coarse: between 1.4 and 2.8 mm) were conditioned to moisture content of 3, 6 and 9 wt%. Considered in the study, are heating temperature ranging from 50 to 150^{o}C in steps of 25 degrees Celsius and heating time of 5 to 25 minutes in steps of 5 minutes. Pressing pressure of 5 to 25 MPa in steps of 5 MPa and pressing time of 2 minutes interval were also considered. The maximum oil yield was then correlated with the processing conditions. Test results showed that coarse particle gave higher oil yield. Maximum oil yield of 72.2% of the available oil was obtained at 6% moisture content, heating temperature of 100^{o}C and heating time of 10 minutes. Regression analyses of the oil yield with heating temperature, heating time, and pressing gave r^2 values of 0.9678, 0.999 and 0.9128. The processing conditions therefore has significantly influence the quantity of oil obtained from Dika kernel.

Key words: Dika nut, oil expression, oil yield, regression analysis, heating temperature.

1. Introduction

The drive towards clean technology stirred up stronger environmental concerns and growing regulations over contamination and pollution of the environment. As a result, use of renewable and biodegradable lubricants which have little or no environmental foot print are being encouraged (Erhan et al., 2006; Nagendramma and Kaul, 2012). Presently, mineral oil based lubricant has the largest share in the lubrication industry, as more than 95% of lubricants are mineral oil based (Gaikwad and Paramjyothi, 2008). Mineral oil based lubricants has been found to contribute immensely to polluting the environment as over 60% of used lubricants are lost to the environment (Mann, 2007). This is further compounded by the non-biodegradability and ecotoxicity of this class of lubricant. Vegetable oils have so far been found a viable alternative to mineral oil as it tends to eliminate the environmental problems associated with mineral oil lubricants (Abidakun and Koya, 2012). In addition to this, they also possess excellent tribological properties such as high viscosity index, high lubricity, high flash point (Balamurugan et al., 2010; Abidakun and Koya, 2009, 2012)

Various vegetable oils have been tested for use as lubricant in place of mineral oil. Among oils that have shown potential for use as lubricants are rape seed oil, soy bean oil, palm kernel oil, palm oil (Sraj et al., 2000; Petlyuk and Adams, 2004; Abidakun and Koya, 2009). Dika nut oil has also been found to possess the qualities of being used as lubricant as it possesses good viscosity index, flash point and moderate pour point (Abidakun and Koya, 2009). However the cost of vegetable oil based lubricants as compared to that of mineral oil has been one of the major factors militating against its widespread use (Mann, 2007).

Proper expression of the oil can serve as a means of reducing the processing cost associated with biodegradable oil. Efficient expression of vegetable oils from oil bearing seeds by mechanical method requires optimum preliminary processing before the expression (Ibrahim and Onwualu, 2005; Mwthiga and Moriasi, 2007). These processing conditions include particle size, moisture content, heating temperature, heating time, pressing pressure and pressing time. Just as processing conditions have shown effect on the thermo-physical properties of expressed dika nut oil (Abidakun and Koya, 2012), processing conditions have also shown effect on the oil yield from many oil bearing materials (Suganya *et al*., 2000; Akinoso *et al*., 2006; Willem *et al*., 2008; Ibrahim and Onwualu, 2005; Mwthiga and Moriasi, 2007).

From the aforementioned, efficient processing of the oil bearing materials prior to expression is necessary in order to achieve higher yield and subsequently cheaper end product. Adequate knowledge of oil yield from the kernel is also required for design and construction of the oil expeller to handle the expression on a large scale. Hence, the objectives of this study is to investigate the influence of particle size, moisture content, heating temperature and heating time, pressing pressure and pressing time on the quantity of oil expressed from Dika nut.

2.0 Materials and Methods

Dika kernel ground to average particle sizes less than 1.4 mm (fine) and between 1.4 and 2.8 mm (coarse) were conditioned to moisture contents of 3, 6 and 9% wt%. Fifty grammes of the sample with fine and coarse particles conditioned to 3% moisture content were heated at 50^oC for 5 minutes. The heated samples were subsequently pressed by applying uniaxial compression load via an experimental pressing rig. Based on the result of the pressing, subsequent experiments were performed on the sample with coarse particles. At 3% moisture content, the samples were further heated at 75, 100, 125 and 150^oC for 5, 10, 15, 20 and 25 minutes. The same combinations of heating temperatures and heating times were considered for moisture contents of 6 and 9%. In each case, pressing pressure of 5 MPa and pressing time of 5 minutes was applied. Pressing pressure of 10, 15, 20 and 25 MPa were also applied at a selected combination of moisture content, heating temperature and heating time. Quantity of oil expressed was measured at intervals of two minutes until there was no considerable increase in oil expressed. Weighing was by the use of electronic weighing balance with 0.01g accuracy. Each of the experimental runs was replicated three times. A summary of the experimental design is as shown in Table 1.

Table 1: Experimental design for the study

S/N	Processing Conditions	Levels
1	Moisture Content, wt%	3, 6, 9
2	Heating Temperature, ^oC	50, 75, 100, 125, 150
3	Heating Time, minutes	5, 10, 15, 20, 25
4	Pressing pressure, MPa	5, 10, 15, 20, 25
5	Pressing time	2 minutes interval
6	Replications	3

3.0 Results and Discussion

3.1 Effect of Particle Size on Oil Yield

Variation in oil yield with particle size at different moisture contents is shown in Fig. 1. Sample with coarse particles (between moisture content of 1.4 and 2.8 mm) yields higher quantity of oil than the sample with fine particles (≤ 1.4). The difference in the yield could be due to the larger surface area which permitted rapid loss of moisture than it was required for sufficient oil extraction in the sample with fine particles. Lower oil yield from samples with fine particles may also be attributed to the ease with which the ducts for oil flow were sealed up by the applied pressure. In both cases of fine and coarse particles, the oil yield reached the maximum value at a moisture content of 6 wt%.

This may be an indication that moisture content and particle size may not really have an interdependent effect on oil yield in mechanical pressing of Dika meal.

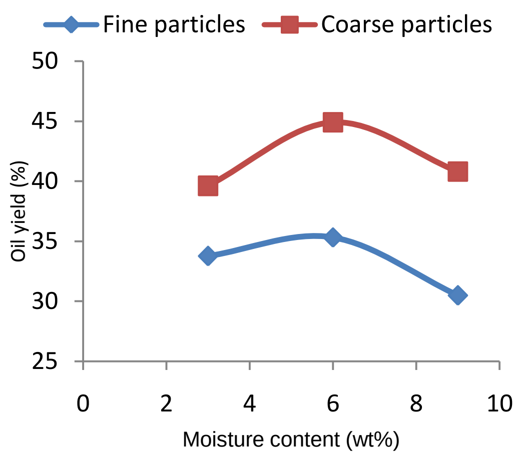

Figure 1: Variation of oil yield with moisture content at different particle sizes

3.2 Effect of Moisture Content, Heating Temperature and Heating Time on Oil Yield

Figures 2, 3 and 4 show the variation of oil yield with heating time and heating temperature at various moisture contents. Continuous decrease in oil yield was noticed as heating temperature increased for samples at 3% moisture content. For samples at moisture contents of 6 and 9%, the oil yield increased with heating temperature, up to 100 and 125^{o}C, respectively before it declined. At moisture content of 3 wt% and heating temperature of 50^{o}C (Fig. 2), the oil yield increased continuously as heating time increased from 5 to 20 minutes. A decline was however noticed at 25 minutes heating time. At higher heating temperatures, the oil yield decreased continuously with increase in heating time. The continuous decrease in oil yield at higher heating temperatures could be due to the fact that the moisture content decreased further as the heating increased (Mwthiga and Moriasi, 2007).

For all other heating times, the oil yield increased continuously for both 6% and 9% moisture contents when heated at 50^{o}C (Figs 3 and 4). The highest oil yield for 50^{o}C heating temperature was obtained at heating time of 25 minutes for sample conditioned to 9 wt% moisture content. There was no oil yield for samples heated at 50^{o}C and 75^{o}C for 5 minutes at both 6 and 9% moisture contents. This was probably due to the low oil temperature attained during these conditions. However, once sufficient heat treatment was accomplished, oil yield was higher at the higher moisture levels of 6 and 9 wt%. This also further confirms the need for adequate preheating of oil seeds in mechanical oil expression.

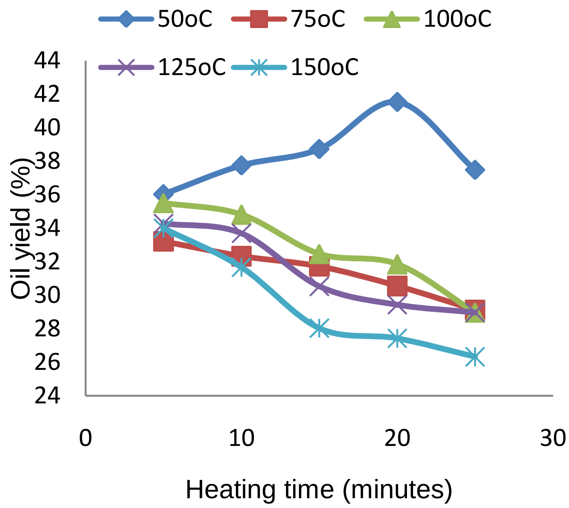

Figure 2: Variation of oil yield with heating time for different heating temperature at 3% moisture content.

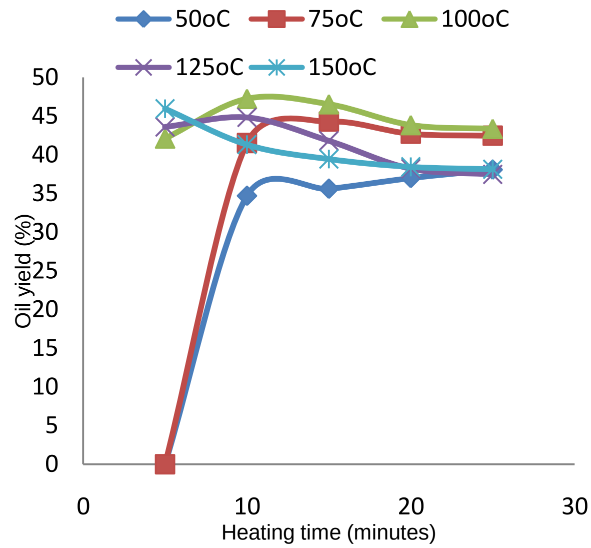

Figure 3 Variation of oil yield with heating time for different heating temperature at 6% moisture content.

Consequently, the combination of heating temperature and heating time is an integrated factor affecting oil yield. This is explicable as it represented the quantity of heat energy added to the sample. Therefore, if the heat energy exceeded the latent heat of vaporisation, the moisture content of the meal is readjusted and if it falls below a threshold, the oil expression is obstructed. Figure 3 shows the oil yield at 75^{o}C; oil yield reached the highest at heating time of 10 minutes and declined thereafter for samples at 6 wt% moisture content. The yield increased till 15 minutes heating time before it declined for samples at 9% moisture content (Figure 4). Samples at 6% moisture content heated for 15 minutes gave the highest yield among the samples heated at 75^{o}C. Samples at 6% moisture content heated at 100 and 125^{o}C gave their maximum yield at heating time of 10 minutes (Fig 3). Oil yield reached the maximum at 5 minutes when it was heated at 150^{o}C and declined continuously thereafter.

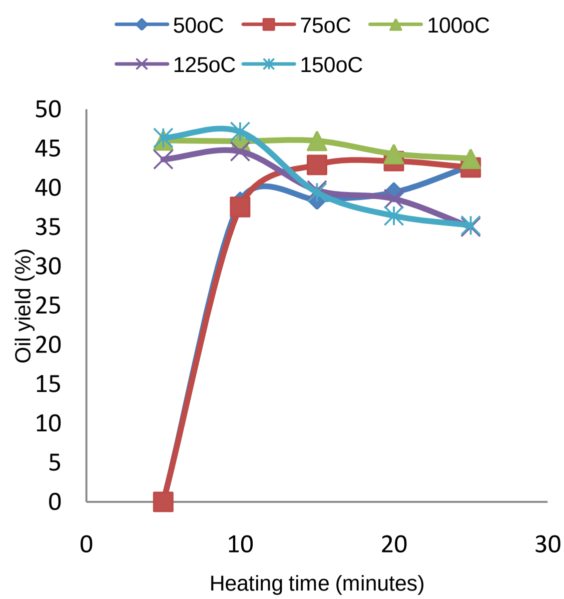

Figure 4: Variation of oil yield with heating time for different heating temperature at 9% moisture content.

Analysis of variance on the significance of the effect of the factors: moisture content, heating temperature and heating time considered showed that all the factors have significant effect ($p \leq 0.05$) on the quantity of oil expressed. Moisture content appeared to be the most significant of the three factors, followed by heating time and thereafter heating temperature. The significance of the interactions among the factors indicates that the factors have interdependent effect on the quantity of oil expressed. This is similar to the case of palm kernel and sesame seed oil expression, where all the factors have significant effect on oil yield (Akinoso, 2006).

3.3 Effect of Pressing Pressure and Pressing Time on Oil Yield

Figure 5 shows the variation of oil yield with pressing time at various levels of pressing pressure when the sample pre-processed at optimum conditions of 6 wt% moisture content, 100°C heating temperature and 10 minutes heating time. It was observed that oil yield increased for all pressure levels considered with the highest oil yield at 25 MPa. The oil yield increased as the pressing time increased for all pressure levels which is in accordance with what was reported for soybean (Mwthiga and Moriasi, 2007).

Furthermore, for all the pressing pressure, almost 80% of the maximum oil yield possible was expressed within the first two minutes of pressing time. Although, the pressing continued up to 24 minutes, only slight increase was noticed in oil yield. Over 92% and 95% of the maximum oil expressed had been expressed at pressing time of 4 minutes and 6 minutes, respectively. At 8 minutes of pressing time, oil yield increased from 44% to 54% with increase in pressing pressure from 5 to 25 MPa.

3.4 Relationship of Oil Yield, Heating Temperature, Heating Time and Pressing Pressure

Oil obtained at 6 wt% moisture content, heating temperature of 100°C, pressure of 5 MPa and pressing time of 10 minutes related with heating time gave a second order polynomial equation (Equation 1). The yield obtained at heating time of 10 minutes also gave polynomial equation of the third order (Equation 2) when related with heating temperature. Correlation with heating temperature and heating time gave r^2 values of 0.9678 and 0.999 respectively. Oil yield obtained at pressing time of 8 minutes was related with pressing pressure by a logarithmic equation with r^2 value of 0.9128.

$$Y = -0.0033T^2 + 0.725T + 6.4692 \quad \ldots \quad \ldots \quad \ldots \quad 1$$

$$Y = 0.0054t^3 - 0.2803t^2 + 4.2983t + 26.936 \quad \ldots \quad \ldots \quad 2$$

$$Y = 5.69\ln P + 36.105 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad 3$$

where Y in % is the oil yield, T in °C is the heating temperature, t in minutes is the heating time and P in MPa is the pressing pressure.

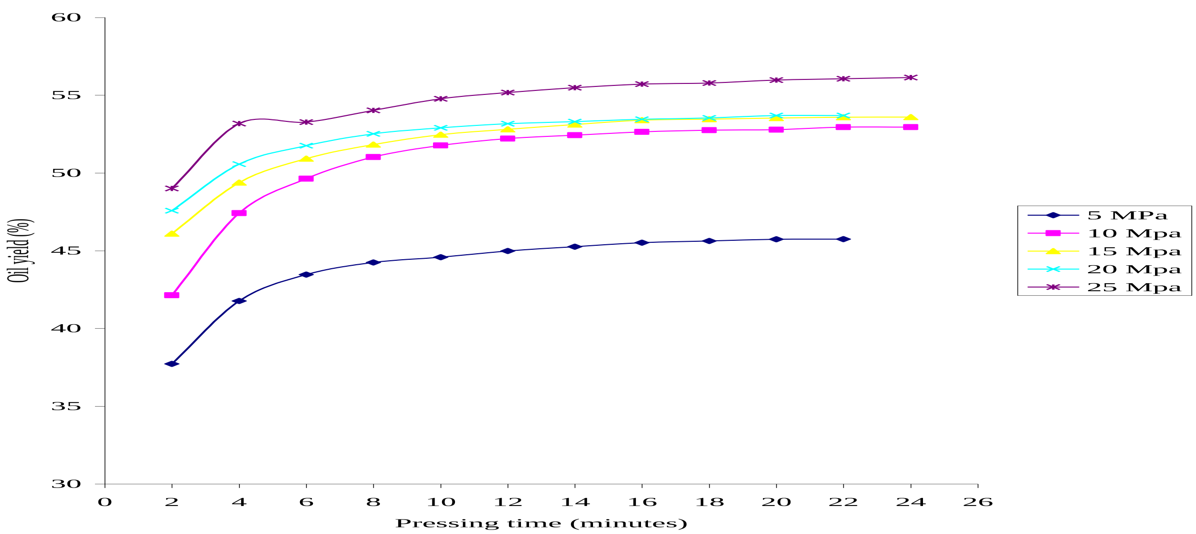

Figure 5: Variation of oil yield with pressing time for different pressing pressure

4. Conclusion

The highest oil yield was obtained from sample with coarse particles conditioned to 6% moisture content on wet basis, heated at 100^{o}C for 10 minutes. It was found that all the three factors: moisture content, heating temperature and heating time; have significant effect on the quantity of oil expressed. Pre-processing moisture content was the most significant. The oil yield increased with increase in pressure within the pressure range of 5 to 25 MPa considered in the study.

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