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Effect of Pre-Treatments on Mechanical Oil Expression from Dika Kernels

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ABSTRACT

The effect of pre-treatments on mechanical oil expression from dika kernels was investigated in this study. The parameters considered were particle sizes (fine and coarse), moisture content (4, 6, and 8%), heating temperature (30, 40, and 50°C), heating time (15, 35 and 45 min) and applied pressure (5, 10 and 15 MPa). The results showed that the oil point pressure of dika kernels reduced with increase in heating temperature and time and moisture content. The highest oil point pressure for coarse particles was recorded at 2.11 MPa; whereas oil point pressure for fine particles was below 1 MPa. The lowest pressure at which oil began to flow was 0.41 MPa (at 50°C and 8.3% MC) while the highest was 0.65 MPa (at 30°C and 4.2% MC). The optimal oil point pressure ranged from 0.55 to 0.65 MPa for fine particles and 1.51 to 2.11 MPa for coarse particles. The least oil yield was at 4% moisture content at 5 Mpa for coarse particles; whereas the highest yield was obtained at 4% moisture content at 15 MPa for fine particles. For coarse particles, resistance to oil flow decreased significantly with increase in moisture content, heating temperature and heating time. The optimal oil expression occurred at pressure range of 0.55 to 0.65 MPa for fine particles and 1.51 to 2.11 MPa for coarse particles. Dika kernel has a high oil content, which makes it valuable for oil production. An understanding of the response of oil yield to various pre-treatments will provide valuable information for the optimization of dika oil expression.

Keywords: Dika kernel, oil expression, pressure, moisture content, temperature, particle size.

Introduction

African bush mango (*Irvingia gabonesis*) is of the *Irvingiaceae* family of tree-plants native to West African (Leakey *et al.*, 2005). Its fruit has an edible, pulpy and fleshy mesocarp embedding a stony nut which when cracked yields a dicotyledonous oil-rich seed otherwise called dika kernel (Ogunsina *et al.*, 2008a; Ogunsina *et al.*, 2008b; Ngondi *et al.*, 2005). Given its high mucilage content, the powdered dika kernels produce a viscous consistency when cooked into *ògbònò* (a choice Nigerian sauce). Dika kernels flour is baked and eaten as dika bread in Ghana, Cameroun, Congo and Gabon; hence it is a widely traded commodity in the region (Leakey *et al.*, 2005). Ogunsina *et al.* (2012) reported that dika kernel contains about 8.9% of crude protein and 68.37% of crude fat largely made up of saturated fat comprising about 62 and 28% of myristic and lauric acids respectively. Such oils solidify at room temperature and do not go rancid easily because of their stable chemical structure. Apart from being a source of energy in human nutrition, some saturated fats carry fat-soluble vitamins A, D, E and K and may serve as valuable nutraceuticals in moderate use (Enig, 1995).

Oil expression from biomaterials may be achieved by mechanical or chemical means involving the use of solvents or enzymes. Although chemical

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extraction usually removes virtually all the oil from the oil-seed meal, the process is quite expensive and risky for village-level application (Ajibola *et al*., 2000; Adeeko and Ajibola, 1990). Mechanical oil expression from oil-bearing materials is a solid-liquid phase separation process which involves the application of pressure by hydraulic or screw press with or without heat. For small and medium scale applications, the hydraulic press is quite appropriate as it requires lower initial costs (Ajibola *et al*., 2000). Under the intense pressure of the hydraulic, the oil bearing cells are weakened; they get ruptured and discharge their contents (Oyinlola and Adekoya, 2004; Ajibola *et al*., 2002; Hamzat and Clarke, 1993). Knowledge of the pressure that will optimize oil recovery from a particular oil seed is therefore very important for the process to be efficient. Usually cold pressing is considered healthier, protects denaturation of valuable nutrients and produces the most natural oil, it is uneconomical for large scale investment because the yield is lower. However, for most oil seeds, certain pre-pressing treatments such as heating, moisture content adjustment and particle size reduction have been applied to make the oil bearing cells discharge their contents more readily to optimize oil yield (Ajibola *et al*., 2002; Ajibola *et al*., 2000; Adeeko and Ajibola, 1990). Specific conditions of pre-treatments required vary from one seed to another (Akintunde *et al*., 2001; Owolarafe *et al*., 2003). Studies in this regard have been conducted on several oilseeds including cashew, locust bean, sesame, soybean, groundnut, conophor and flaxseed (Ogunsina *et al*., 2008c; Owolarafe *et al*., 2003; Ajibola *et al*., 2002; Akintunde *et al*., 2001; Ajibola *et al*., 2000; Adeeko and Ajibola, 1990; Fasina and Ajibola, 1989; Dedio and Dornell, 1977). It provides useful information for design or adaptation of existing machines for oil expression and performance evaluation of same. However, inspite of the broad-based food application of African bush mango kernels, information regarding its oil expression is rarely available in literatures.

This study was therefore undertaken to investigate the effect of pre-treatments involving moisture content, heating temperature and heating time on yield of mechanically expressed oil from African bush mango kernels.

Material and Methods

Source of materials and sample preparation

Dika kernels procured from a local market in Gbongan, Osun state, Nigeria were used for this investigation. Foreign and extraneous materials were removed from the lot manually. Particle size reduction was carried out in an attrition mill and the material was graded into coarse and fine particles using mechanical sieve (Ogunsina *et al*., 2008c). Coarse particles passed through 4.75 mm sieve but were retained on 2 mm sieve while fine particles passed through 2 mm sieve (Fig. 1). Each particle size was subdivided into three equal parts and the moisture content of each portion adjusted to 4, 6, and 8% (wet basis) respectively. The specific quantity of water required to be added to each portion was determined as documented by Ogunsina *et al.* (2008c):

$$MC_{db} = \frac{MC_{wb}}{100 - MC_{wb}} \times 100 \quad (1)$$

and

$$M_m = M_{Cdb} \times M_d \quad (2)$$

where, MC_{db} = Moisture Content dry basis;
MC_{wb} = Moisture Content wet basis;
M_d = Mass of dry matter;
M_w = Mass of water to be added

The conditioned samples were sealed in polyethylene bags and stored in a freezer at -10°C until the time of use below 48 h (Ogunsina *et al*., 2008c; Ajibola *et al*., 2002; Ajibola *et al*., 2000; Adeeko and Ajibola, 1990). The samples were removed from the freezer and allowed to thaw completely until equilibrium was attained. The actual moisture contents of the samples after equilibration were determined by AOAC method (AOAC, 2000).

Pressing

The hydraulic press used for this experiment (Fig. 2) was earlier reported by Ogunsina *et al.* (2008c), Ajibola *et al.* (2000), Adeeko and Ajibola (1990) and some other previous researchers. The chosen factor levels were based on review of literatures and baseline studies. Preliminary investigation on the oil point pressure of dika kernels was carried out using a 20 metric tons hydraulic jack to apply pressure on the sample as earlier reported for sesame, soy bean, cashew, locust bean and sunflower (Ogunsina *et al.*, 2008c; Owolarafe *et al.*, 2003; Ajibola *et al.*, 2002; Ajibola *et al.*, 2000). It was found that at temperatures above 50^{o}C, applying the lowest pressure obtainable from the press (0.036 MPa), dika oil flowed freely, thus oil point pressure could not be established at above 50^{o}C. Therefore, temperature levels were limited to 30, 40 and 50^{o}C.

For each run, samples were put inside a cylindrical press cage with 2 mm holes drilled at its base to allow oil passage during pressing. Before filling the cylinder, the holes around the lower perimeter of its perforated base were stuffed with tiny strips of white tissue paper such that they projected into the cylinder. This helps to spot oil and identify the pressure just at which oil point would be attained (Ogunsina *et al.*, 2008c; Ajibola *et al.*, 2002; Ajibola *et al.*, 2000; Dedio and Dornell, 1977). The cylindrical press cage containing the sample was placed under the piston. Known weight was added to the loading drum while the lever arm was suspended by the hydraulic jack. Afterwards, the jack was released gradually to allow the suspended lever arm to rest on the pressing ram and piston. The pressure generated was transferred through the cylinder onto the sample. The jack was used to lift the lever arm in order to remove the cylinder and piston. After each pressing operation, the tissue paper strips in the holes of the cylinder were removed and examined for oil marks; the distance from this point to the support was measured and converted to pressure using the principle of moment of forces. There were three replicates for each run.

Determination of oil yield

In determining oil yield under different pre-treatments, known weight was added to the drum in order to generate the required pressure, the oil point having been known. For each experimental run, about 30 g of the sample was heated and moisture loss was recorded by subtracting the weight after and before heating. The sample were wrapped in a cheese cloth and carefully lowered inside the pressing cage so as to allow the lever arm to rest on the pressing ram and piston. After each operation, the volume and the weight of the oil expressed were measured and recorded (Ogunsina *et al.*, 2008a; Fasina and Ajibola, 1989). There were three replications for each experimental run.

Results and Discussion

The actual moisture contents of the samples were 4.2, 6.5 and 8.3% (wet basis) but for easy reference in this report, the levels are referred to as 4, 6, and 8%. The oil point pressure of fine and coarse dika kernel particles as influenced by the pre-treatments are presented in Tables 1 and 2 respectively. In Table 1, the lowest pressure at which oil flow was observed was 0.41 MPa (at 50^{o}C, 8% MC and 45 min of heating) which differs significantly ($p < 0.05$) from mean pressure at all other combination of pre-treatment. The highest pressure was 0.65 MPa (at 30^{o}C, 4% MC and 15 min of heating), which was not significantly different from values obtained at a heating temperature of 30 and 40^{o}C. It may therefore be inferred that in the range of experimental values, for fine particles, oil point pressure ranged between 0.65 and 0.41 MPa.

Considering Table 2, for coarse particles, the lowest pressure at which oil flow was observed was 1.51 MPa, (at 50^{o}C, 8% MC and 45 min of heating). This value is significantly different ($p < 0.05$) from values of mean pressure at other combinations of pre-treatment. However, the highest was 2.11 MPa (at 30^{o}C, 4% MC and 15 min) which stands out above all other pre-treatment. It may be inferred summarily that for coarse particles, oil point pressure ranged between 1.51 and 2.11 MPa. These results show that for both particle sizes of dika kernel, oil point pressure reduced as heating temperature, heating time and moisture content increased. In the presence of excess moisture the liquid phase bears the entire load itself being incompressible and does not exert any pressure on the oil bearing particles; the oil bearing cells get swollen. This increases the pressure on the cell wall, further application of pressure ruptures and forces them to discharge their contents and adversely affects oil expression (Bamgboye and Adejumo, 2011).

Table 1: Effect of pre-treatment of fine particles of dika kernels on oil point pressure

Heating temperature (^{o}C)	Heating time (mins)	Moisture content (%)		
		4	6	8
		Mean pressure (MPa)		
30	15	0.65^{a}	0.63^{a}	0.61^{a}
	30	0.64^{a}	0.61^{a}	0.60^{a}
	45	0.64^{a}	0.60^{a}	0.59^{a,b}
40	15	0.63^{a}	0.60^{a}	0.59^{a,b}
	30	0.63^{a}	0.59^{a,b}	0.58^{a,b}
	45	0.61^{a,b}	0.57^{b,c}	0.57^{a,b}
50	15	0.62^{a}	0.57^{b,c}	0.57^{a,b}
	30	0.59^{b}	0.55^{c}	0.54^{c}
	45	0.43^{c}	0.41^{d}	0.41^{d}

^{a,b,c,d}Means on the same column with different letters are significantly different ($p < 0.05$).

In previous studies, Ajibola *et al.* (2000) and Akintunde *et al.* (2001) stated that when an oilseed is subjected to heat treatment, moisture loss creates a void which serves as migratory space for the contents of the oil bearing cells thereby facilitating the rupture of oil bearing cells as heating progresses. In addition, this lowers viscosity of oil and coagulates the protein, thus enabling oil to emerge from the oil-bearing cells into the inter-kernel void (Adeeko and Ajibola, 1990). Moreover, dika seed oil normally solidifies at room temperature, above which it melts due to its high myristic acid content (Ogunsina *et al.* 2012). When temperature increases or heating is prolonged, the tendency is for oil to flow more readily from the oil bearing cells. Similar results had been reported for cashew kernel, locust bean, soybean and groundnut (Ogunsina *et al.* 2008c; Owolarafe *et al.*, 2003; Ajibola *et al.*, 2000; Adeeko and Ajibola, 1990).

Table 2: Effect of pre-pressing treatment of coarse particles of dika kernels on oil point pressure

Heating temperature (^{o}C)	Heating time (mins)	Moisture content (%)		
		4	6	8
		Mean pressure (MPa)		
30	15	2.11^{a}	1.97^{a}	1.88^{a}
	30	1.70^{c,d}	1.82^{a,b}	1.77^{b}
	45	1.65^{c}	1.62^{c}	1.62^{c}
40	15	1.99^{a}	1.83^{a,b}	1.71^{b}
	30	1.88^{a,b}	1.73^{b}	1.66^{c}
	45	1.76^{b}	1.63^{c}	1.55^{d}
50	15	1.76^{b}	1.64^{c}	1.55^{d}
	30	1.64^{d}	1.61^{c}	1.53^{d}
	45	1.61^{d}	1.59^{c}	1.51^{e}

^{a,b,c,d,e}Means on the same column with different letters are significantly different ($p < 0.05$).

Figure 3 further established that the average oil point pressure for fine particles was far less than that of coarse particles. This conforms with expectation and previous reports that mechanical oil expression is achievable at relatively lower pressure with fine particles than with coarse particles (Akintunde *et al.*, 2001; Fasina and Ajibola, 1990). Figure 4 shows the relationship between dika kernel particle sizes and oil yield under varying pressures. It was observed that oil yield of fine particles was more than that of coarse particles as applied pressure varied from 5 MPa to 15 MPa. The highest oil yield (36.6%) was obtained with fine particles at 15 MPa while the lowest oil yield (17.5%) was obtained at 5 MPa for coarse particles. This may be due to the fact that a larger surface area of fine particles was exposed to moisture, heat and pressure. The oil cells of fine particles ruptured and collapsed more quickly under the applied pressure since larger surface area were exposed to the applied pressure. This result corroborates previous findings for soybean, groundnuts, and conophor nut (Akintunde *et al.*, 2001; Adeeko and Ajibola, 1990; Fasina and Ajibola, 1989).

The relationship between moisture content, applied pressure and oil yield of dika kernel is shown in Fig. 5. The most common trend was that oil yield increased as moisture content and pressure increased. For fine particles, at 10 and 15 MPa of applied pressure, oil yield decreased as the MC varied between 6 and 8%. Generally for fine particles, the mucilage that dika kernel contains will normally get swollen in the presence of moisture; and this blocks oil passage which consequently hinder oil flow thereby reducing oil yield. Similar behavior may be found with oil seeds with high mucilage content such as flax and okra seeds. The least oil yield recorded for coarse particles was at 4% MC and 5 MPa whereas the highest was obtained for fine particles at 4% at 15 MPa.

Conclusions

The effect of pre-treatments on mechanical oil expression from dika kernels has been investigated and the following conclusions can be drawn.

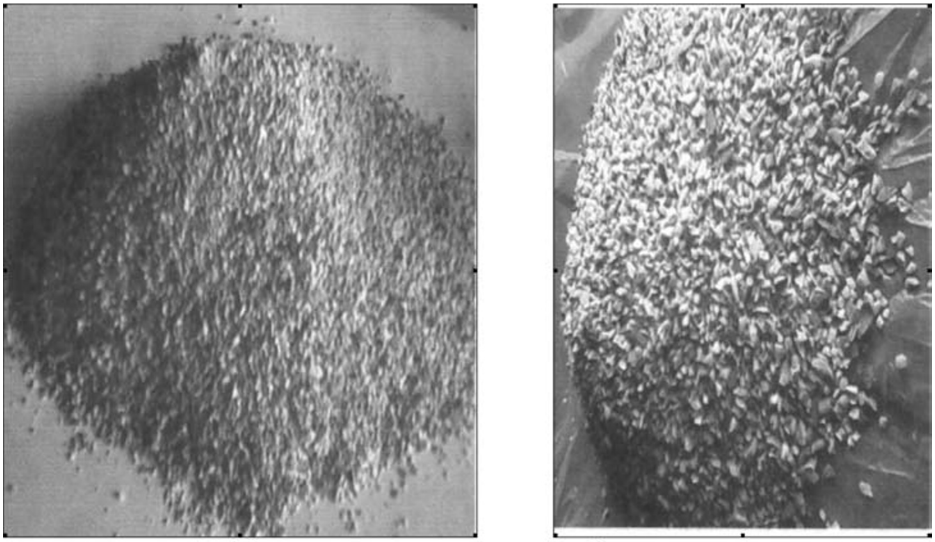
(i) Oil point pressure reduced as heating temperature, heating time and moisture content increased. For fine particles, oil point pressure ranged between 0.65 and 0.41 MPa whereas for coarse particles, oil point pressure ranged between 1.51 and 2.11 MPa.

(ii) For dika kernels oil point pressure could not be established at above 50^{o}C. At temperatures above 50^{o}C, dika oil flowed freely when the lowest pressure obtainable from the press (0.036 MPa) was applied.

(iii) The most common trend was that oil yield increased as moisture content and pressure increased. For fine particles, at 10 and 15 MPa of applied pressure, oil yield decreased as the MC varied between 6 and 8%.

(iv) The least oil yield recorded for coarse particles was at 4% MC and 5 MPa whereas the highest was obtained for fine particles at 4% at 15 MPa.

Fig. 1a: Dried dika kernels



Fine Coarse

Fig. 1b: Fine and coarse aggregates of dika kernels

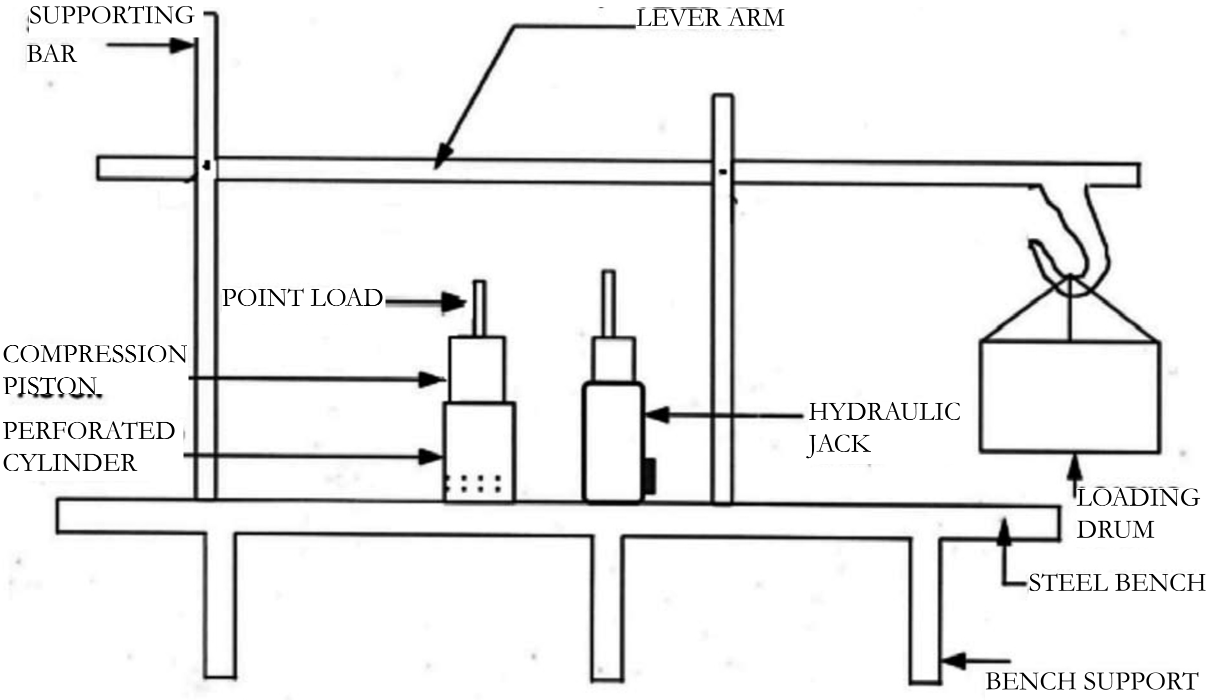


Fig. 2: Schematic diagram of the laboratory press used for this investigation

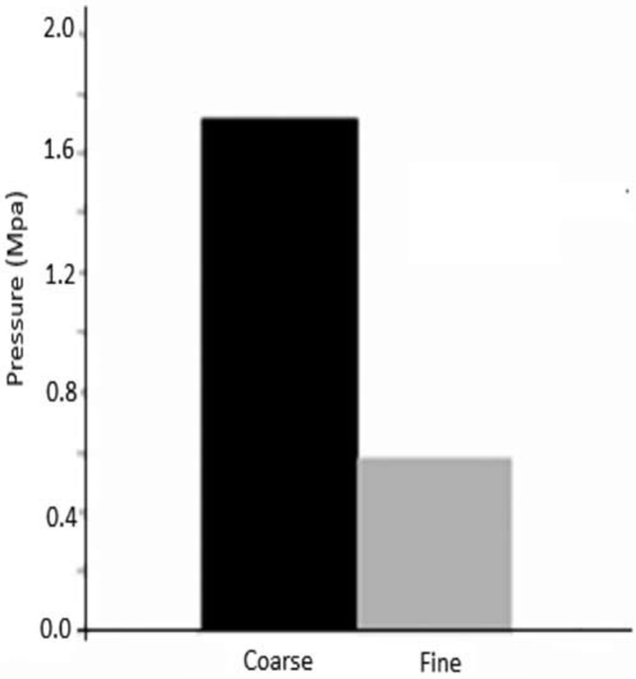


Fig. 3: Effect of particle sizes on dika kernels oil point pressure

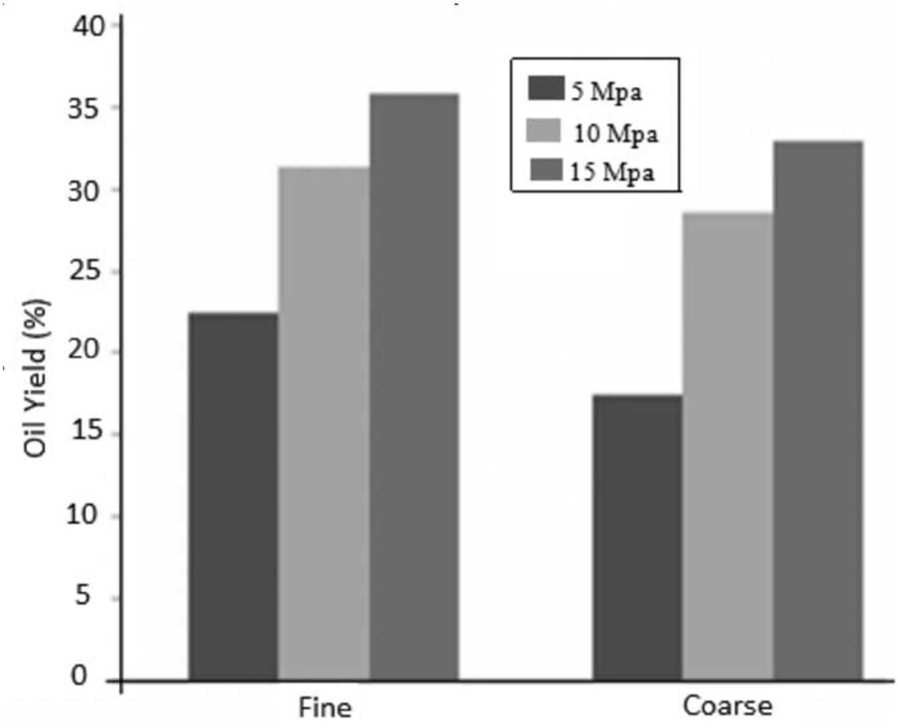


Fig. 4: Effect of particle sizes and applied pressure on dika kernels oil yield

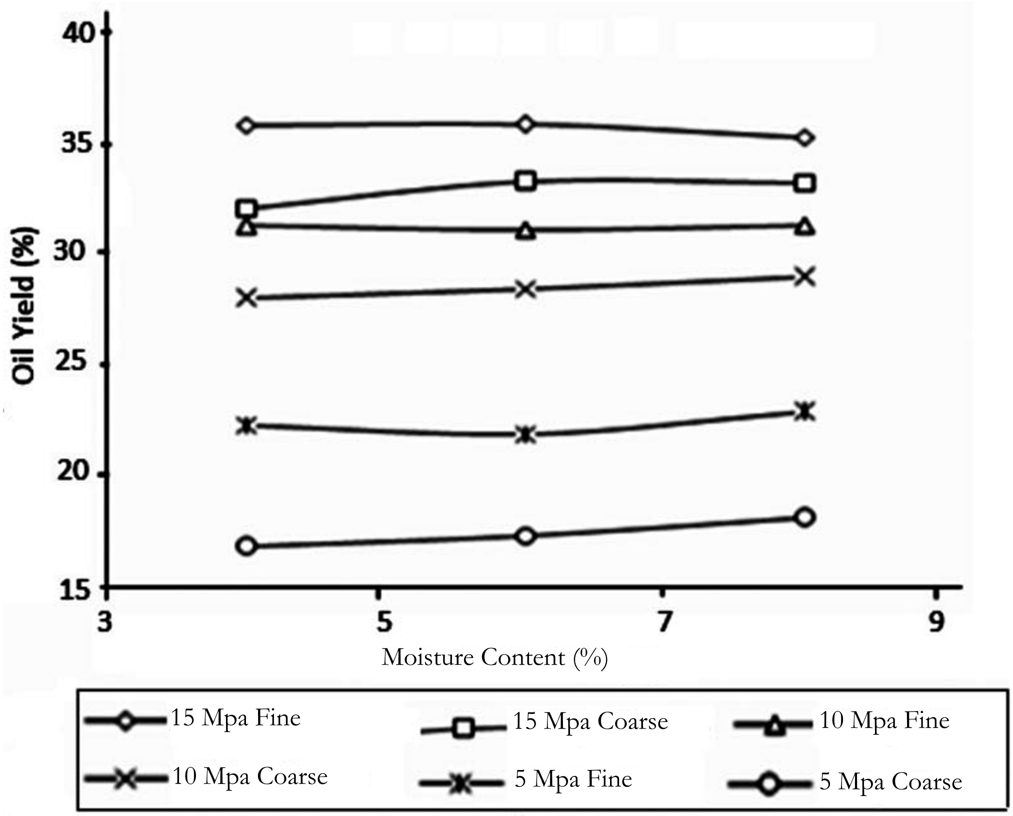


Fig. 5: Effect of applied pressure on dika kernels oil yield

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