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Effect of Processing Conditions on Oil Point Pressure of Calabash Nutmeg

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ABSTRACT: *The oil point pressure of calabash nutmeg (Monodora myristica) was investigated considering particle size, moisture content, heating temperature and heating time. Freshly harvested seeds obtained from a local market in Ibadan were decorticated and cleaned of all extraneous matter. The kernels obtained were milled and graded into fine and coarse aggregates. The experiment was a central composite design in which two levels of moisture content (17 and 21%wb), heating temperature (50 and 70 ℃) and time (5 and 15 mins) were considered. The data obtained were analyzed using Design Expert Version 6.0.8. The results showed that oil point pressure increased with time but decreased as heating temperature and moisture content increased. For fine aggregates, the minimum oil point pressure of 0.116 MPa was obtained at a temperature, time and moisture content combination of 60 ℃, 10 mins and 23%wb, respectively. However, for coarse aggregates, the minimum oil point pressure of 0.144 MPa was obtained at 70 ℃, 5 mins of heating time and moisture content of 21% (w.b). The results showed that the oil point pressure of fine aggregates was lower than that of the coarse aggregates. From the analysis of variance, heating time had significant effect on the oil point pressure (p<0.05). The minimum oil point pressure of calabash nutmeg was obtained as 0.116 MPa at an optimal temperature, time and moisture content of 64 ℃, 5 mins and 21% (w.b), respectively.*

KEYWORDS: Oil expression, *Monodora myristica*, Oil point pressure, Optimization, Processing conditions.

INTRODUCTION

Calabash nutmeg (*Monodora myristica*), hereinafter referred to as *M. myristica* is a tropical tree in the *Annonaceae* family of plants, native to tropical West Africa where it grows naturally in evergreen forests (Talalaji, 1999). The tree bears a spherical berry fruit which turns greenish yellow when mature, bearing several smooth, pale brown, peanut-sized seeds in a nut-shell which turns woody when dry. The seeds are widely used as an inexpensive substitute for nutmeg because of their similarities in aroma and taste. The seed oil has a characteristic nutmeg flavour which makes it suitable for cooking in some West Africa countries (Eggeling, 2002). Studies on the proximate composition of *M. myristica* seeds indicated about 22.7, 19.1, 2.6, and 28.4% of crude fat, crude fibre, ash and carbohydrate, respectively (Ayelaagbe *et al.*, 1996). Phytochemical screening of the crude extracts of *M. myristica*, seeds revealed the presence of some bioactive components such as phenols, alkaloids, flavonoids, saponins and tannins (Iwu, 1993). Bioactive compounds have been widely proven to be active against human pathogens (Cowan, 1999; El-Mahmood, 2008 and Enabulele and Ehiagbonare, 2011). In some parts of West Africa (notably, Ghana), *M. myristica* extract is used for treating certain skin infections due to its antimicrobial properties (Irvine, 2000; Talalaji, 1999).

There are many literatures regarding seed oil expression by solvents or mechanical methods (using hydraulic or screw presses). Some of such previous works include oil expression from groundnut, soybean, cotton seed, palm kernel, sesame seed, sunflower, cashew nut and moringa (Koo *et al.*, 1987; Ajibola *et al.*, 2002; Oyinlola and Adekoya, 2004; Singh *et al.*, 2004; Ogunsina *et al.*, 2008 and Aviara *et al.*, 2014). The oil point pressure is the threshold pressure at which oil emerges from an oil-bearing seed when it is subjected to compression (Ogunsina *et al.*, 2008). Such studies have also been documented for many oilseeds. It is a valuable information in the design and performance evaluation of oil expellers or adaptation existing machines for any particular oilseed. The major pretreatment or processing conditions known to influence oil yield have been established as heating temperature, time, moisture content and particle size (Oyinlola and Adekoya, 2004; Aviara *et al.*, 2014, Ogunsina *et al.*, 2008, Owolarafe *et al.*, 2003). However, data regarding oil expression from *M. myristica* seeds or its oil point pressure are rarely found in literature. In this study, the effect of processing parameters (particle size heating temperature, time and moisture content), on the oil point pressure of *M. myristica* seeds was investigated.

MATERIAL AND METHODS

Source of Material

Monodora myristica seeds weighing 5 kg was sourced from orchard trees in the botanical garden of Obafemi Awolowo University, Ile Ife, Nigeria. The seeds were cleaned and sorted to remove extraneous materials. The initial moisture content of the seed was 15% (wb).

Sample Preparation and Conditioning

The samples were milled and graded into fine and coarse aggregates using sieves sizes 2 mm and 4.75 mm respectively. The initial moisture content was determined by AOAC (2000) method. The moisture contents of samples were adjusted to three moisture levels; 17, 19 and 20% moisture content (wb). The samples with adjusted moisture levels were sealed in polythene bags and stored in a 5℃ conditioned environment until the time of use (Ogunsina *et al.*, 2008; Ajibola *et al.*, 2002; Ajibola *et al.*, 2000). The samples were removed from the refrigerator and allowed to equilibrate. About 30 g of the samples were heated in an oven considering three levels of temperature (50, 60 and 70℃) and heating time (5, 10 and 15 mins).

Pressing

The laboratory press used for the oil expression has been widely reported by other researchers (Ajibola *et al.*, 2002; Owolarafe *et al.*, 2003; Oyinlola and Adekoya, 2004; Ogunsina *et al.*, 2008, Tunde-Akintunde, 2010; Aregbesola *et al.*, 2012 and Aviara *et al.*, 2014). It consists of a lever which served as a pressure transfer medium had a dead weight of 90 kg and an effective length of 3000 mm. The weight of the loading drum was 30 kg. The pressure transferred from the lever arm to the sample in the test cylinder through the point load and piston was varied by moving the cylinder and its content along the lever arm. The test cylinder was a 50 mm long galvanized steel pipe with an internal diameter of 40 mm. The cylinder had one of its ends closed with a 12 mm thick metal base with 2 mm holes drilled at a pitch of 15 mm. The holes were blocked by strip of tissue papers to permit immediate recognition oil as the earliest as it starts to flow. The piston was a solid steel cylinder, 70 mm long and 39 mm in diameter. A 20 metric tonnes hydraulic jack was used to raise and lower the lever bar for applying pressure to the sample. The cylinder 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. The jack was released gently to allow the suspended lever arm to lower down gradually to rest on the pressing ram and piston. The pressure generated was transferred through the cylinder onto the kernels. The jack was used to lift the lever arm in order to remove the cylinder and piston. After the pressing operation; the jack was used to lift the lever arm in order to check the strips of tissue papers for oil stains. Oil stains on the tissue indicates that the oil point pressure has been reached. If there was no oil stain, the procedure was repeated with a reduction in distance between the lever support and the cylinder position to increase the pressure. When the tissue paper strips were completely soaked, the procedure was repeated with increase in the distance between the support and cylinder position to reduce pressure. The distance from the point where the piston touched the lever arm was measured and converted to pressure using the principle of moment of forces. Oil point pressure was derived as an average of three replicates in each case (Ogunsina *et al.*, 2008).

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Experimental Design

The experiment was a Central Composite Design considering the processing parameters shown in Table 1. The data obtained were analyzed using Design Expert Version 6.0.8 and test of significance was carried out at 5% level of significance. The optimal processing conditions was obtained as a combination of parameters that gave the lowest oil point pressure.

Table 1: Actual levels of the processing conditions

Factor	Name	Type	Low Actual	High Actual	Low Coded	High Coded
A	Moisture Content wb (%)	Numeric	17	21	-1	1
B	Temperature (℃)	Numeric	50	70	-1	1
C	Heating Time (mins)	Numeric	5	15	-1	1

RESULTS AND DISCUSSION

Effect of Processing Conditions on Oil Point Pressure of Fine and Coarse Aggregates of Calabash Nutmeg

The average oil point pressures of fine and coarse aggregates under different processing conditions of heating temperature, heating time and moisture content are shown in Table 2. The results showed that for fine aggregates, the oil point pressure reduced with increase in heating temperature at all moisture levels. For example, as temperature increased from 50 to 70℃ at a moisture content of 21% (wb), heating time of 15 mins, oil point pressure reduced from 0.167 MPa to 0.129 MPa for fine aggregates. For coarse aggregates, as temperature increased from 50℃ to 70℃ at 21% moisture content (wb) for heating time of 15 mins, oil point pressure reduced from 0.221 to 0.153 MPa. The decrease in the oil point pressure was as a result of temperature rise during heat treatment which led to moisture loss thus facilitated rupturing of oil bearing cells as reported by Adeeko and Ajibola, (1990). In addition, there was also decrease in the oil viscosity which enabled oil to ooze out of the oil bearing cells (Ajibola *et al.*, 1993). Similar results were obtained by Ajibola *et al.* (2002) and Owolarafe *et al.* (2003) for the oil point pressure of soybean and locust bean seed respectively. Oil expression was not observed for experimental run nineteen as shown in Table 2 because it was the run with raw aggregates that was not preprocessed which served as the control.

Furthermore, it was observed that oil point pressure decreased with increase in moisture content. It can be seen in Table 2 that for fine aggregates, as moisture content increased from 17 to 21% (wb) at temperature of 50℃ for 5 mins, the average oil point pressure reduced from 0.136 to 0.122 MPa. It can also be seen that for coarse aggregates, as moisture content increased from 17 to 21% at temperatures of 50℃ for 5 mins, the average oil point pressure reduced from 0.166 to 0.151 MPa. This was because there was adequate moisture to transfer oil from the oil bearing cells. It was also observed that increase in the moisture content of the oil-bearing cells weaken the cells therefore require less pressure to express oil from the seed (Ogunsina, 2008). In addition, it was observed that increase in heating time increased the oil point pressure. It can be seen from Table 2 that as the heating time increased from 5 to 15 mins at temperature of 70℃ and moisture content of 17%, the average oil point pressure increased from 0.127 to 0.130 MPa for fine aggregates. It can also be seen that if heating time was increased from 5 to 15 mins at temperature of 70℃ and moisture content of 17% wb, the average oil point pressure increased from 0.1546 to 0.1763 MPa for coarse aggregates.

Analysis of Variance (ANOVA) for the Fine and Coarse Aggregates

The data obtained was subjected to Analysis of Variance (ANOVA) and Design Expert software was used to establish a model that expresses the relationship existing between the oil point pressure of calabash nutmeg seed and processing parameters (Table 3a and Table 3b). For fine and coarse aggregates, heating time has significant effect on the oil point pressure ($p < 0.05$). Since heating time was significant in its linear and square terms (C and C^2), it implies that it can limit oil point pressure and any little variation will significantly affect oil point pressure. The polynomial model in terms of coded factors and actual factor relating the oil point pressure with independent variables, moisture content (A), temperature (B), heating time (C) is presented in equations 1 and 2: Oil Point Pressure = $0.137982 + 0.000902A - 0.00448B + 0.014768C - 0.00015A^2 + 0.000351B^2 - 0.01503C^2 - 0.00466AB + 0.006543AC - 0.00383BC$ (1)

The final Equation in Terms of Actual Factors:

Oil Point Pressure = $0.12178 + 0.009346*MC + 0.004323*T + 0.007138*HT - 3.8E\text{-}05*MC^2 + 3.51E\text{-}06*T^2 - 0.0006*HT^2 - 0.00023*MC*T + 0.000654*MC*HT - 7.7E\text{-}05*T*HT$ (2)

Table 2: Effect of processing conditions on oil point pressure of fine aggregates of calabash nutmeg

				Oil Point Pressure (Pa)	
Run	**A: Moisture Content (%)**	**B: Temperature (°C)**	**C: Heating Time (mins)**	**Fine Aggregates**	**Coarse Aggregate**
1	21	50	15	0.167	0.221
2	17	50	5	0.136	0.166
3	23	60	10	0.116	0.153
4	21	70	15	0.129	0.156
5	19	40	10	0.127	0.194
6	19	60	10	0.121	0.148
7	21	70	5	0.119	0.144
8	17	50	5	0.125	0.166
9	21	50	5	0.122	0.151
10	19	60	10	0.121	0.148
11	21	70	5	0.119	0.144
12	17	70	5	0.127	0.155
13	17	50	15	0.130	0.184
14	19	80	10	0.118	0.164
15	21	50	5	0.122	0.151
16	19	60	20	0.122	0.168
17	21	50	15	0.166	0.221
18	17	70	15	0.130	0.176
19	19	60	0	0	0
20	17	70	5	0.127	0.155
21	17	50	15	0.130	0.184
22	15	60	10	0.124	0.219
23	21	70	15	0.129	0.156
24	17	70	15	0.130	0.176

Table 3a. Analysis of variance for fine aggregates

Source	Sum of Squares	DF	Mean Square	F Value	Prob> F	
Model	0.012476	9	0.001386	2.771098	0.0427	Significant
A	1.95E-05	1	1.95E-05	0.039052	0.8462	
B	0.000483	1	0.000483	0.96458	0.3427	
C	0.005234	1	0.005234	10.46396	0.0060	Significant
A^2	3.77E-07	1	3.77E-07	0.000753	0.9785	
B^2	1.97E-06	1	1.97E-06	0.003936	0.9509	
C^2	0.003614	1	0.003614	7.224464	0.0177	Significant
AB	0.000347	1	0.000347	0.694536	0.4186	
AC	0.000685	1	0.000685	1.369148	0.2615	
BC	0.000234	1	0.000234	0.468305	0.5049	
Residual	0.007003	14	0.0005			
Lack of Fit	0.006946	5	0.001389	218.7536	< 0.0001	Significant
Pure Error	5.72E-05	9	6.35E-06			
Cor Total	0.019479	23				

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Table 3b. Analysis of Variance for coarse aggregates

Source	Sum of Squares	DF	Mean Square	F Value	Prob> F	
Model	0.032281	9	0.003587	6.133687	0.0014	Significant
A	0.000952	1	0.000952	1.627699	0.2228	
B	0.002417	1	0.002417	4.132562	0.0615	
C	0.013982	1	0.013982	23.91001	0.0002	Significant
A^2	0.001461	1	0.001461	2.49821	0.1363	
B^2	0.000962	1	0.000962	1.645608	0.2204	
C^2	0.004115	1	0.004115	7.036876	0.0189	Significant
AB	0.000668	1	0.000668	1.142725	0.3032	
AC	0.000439	1	0.000439	0.751481	0.4006	
BC	0.00076	1	0.00076	1.29951	0.2734	
Residual	0.008187	14	0.000585			
Lack of Fit	0.008187	5	0.001637	76446.97	<0.0001	Significant
Pure Error	1.93E-07	9	2.14E-08			
Cor Total	0.040468	23				

Moisture content: A Temperature: B Heating time: C

Interaction between Processing Conditions as Represented on 3D Response Surface

Figure 1 shows the 3D response surface interaction between the moisture content and heating time keeping temperature constant at 60℃. As shown in Figure 1, it can be observed that for all heating time, oil point pressure decreased as moisture content

increased from 17% and reached minimum at 19% after which it started increasing. Also, for all moisture content, oil point pressure increased as heating time increased from 5 mins and reached maximum at 12.5 mins after which it started decreasing.

Figure 2 shows the 3D response surface interaction between temperature and heating time keeping moisture content constant at 17%. As shown in Figure 2, it can be observed that for all heating time, oil point pressure decreased as heating temperature increased from 50℃ and reached minimum at 60℃ after which it started increasing. Also, for all heating temperature, oil point pressure increased as heating time increased from 5 mins and reached maximum at 12.5 mins after which it started decreasing.

The effect of interaction between heating temperature and moisture content as represented on 3D response surface is shown in Figure 3. As shown in Figure 3, for all heating time, oil point pressure decreased as moisture content increased from 17% and reached minimum at 19% after which it started increasing. Also, for all moisture content, oil point pressure decreased as heating temperature increased from 50°C and reached minimum at 60℃ after which it started increasing.

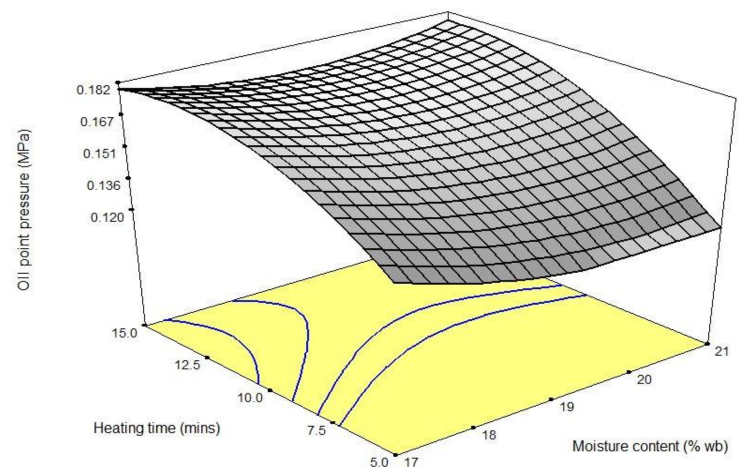

Figure 1. Effect of interaction between moisture content and heating time on oil point pressure as represented on 3D response surface.

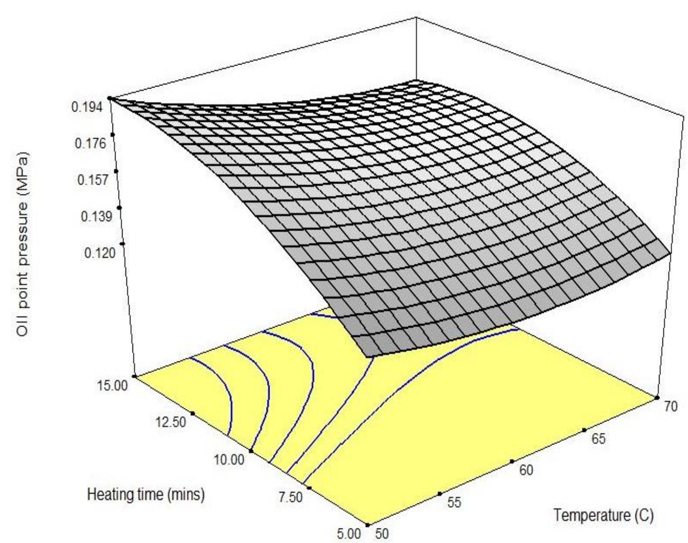

Figure 2. Effect of interaction between heating time and heating temperature on oil point pressure as represented on 3D response surface.

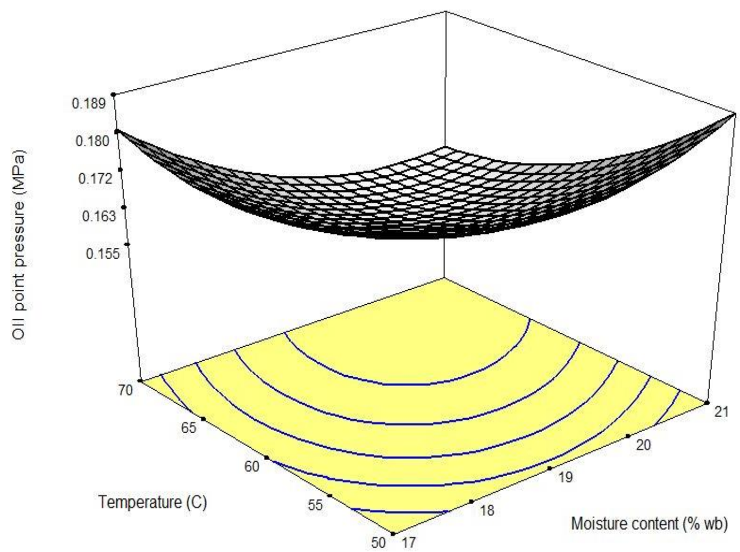

Figure 3. Effect of interaction between heating temperature and moisture content on oil point pressure as represented on 3D response surface.

Oil Point Pressure Optimization of Calabash Nutmeg

The optimization of the oil point pressure was done using Design expert V 6.0.8. This was done to determine the best combination of the processing conditions to obtain minimum oil point pressure. The constraint of the pre-pressing parameters were set in ranges and the oil point pressure was minimized as shown in Table 4a and the results of the optimization is shown in Table 4b. The combination of parameters with highest desirability as shown in Table 4b are moisture content at 20.82%, temperature at 64.41^{o}C and heating time at 5.01 mins leading to minimum oil point pressure of 0.1161 MPa for the coarse aggregates.

Table 4. Optimization of oil point pressure:
(a) Constraint of parameters

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
Moisture Content	is in range	17	21	1	1	3
Temperature	is in range	50	70	1	1	3
Heating Time	is in range	5	15	1	1	3
Oil Point Pressure	Minimize	0.1163	0.2208	1	1	3

(b) Solutions

Number	Moisture Content	Temperature	Heating Time	Oil Point Pressure	Desirability	
1	20.82	64.41	5.01	0.1161	1	Selected
2	20.48	65.20	5.05	0.1163	1	
3	20.46	65.28	5.02	0.1159	1	
4	20.41	65.72	5.03	0.1161	1	
5	20.10	66.02	5.00	0.1163	0.9999	
6	20.33	61.90	5.00	0.1165	0.9989	
7	21.00	70.00	9.35	0.1525	0.6538	
8	19.79	70.00	15.00	0.1587	0.5950	

CONCLUSIONS

This study established that processing conditions affect the pressure at which oil expression from calabash nutmeg is achievable. Increase in heating temperature decreases the oil point pressure. Adequate heat treatment caused breakdown of oil cells and moisture loss from the inner cells where they are held bound. In addition, oil point pressure decreased as moisture content increased, and it decreased as heating time increased. The optimum conditions for the minimum oil point pressure (0.116 MPa) for calabash nutmeg were moisture content - 20.82%, temperature - 64.41℃ and heating time - 5.01 mins. Fine aggregates indicated lower oil point pressure than coarse aggregates. This finding provides data that may assist processing and oil expression from calabash nutmeg seeds.

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