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ORIGINAL ARTICLE

Effect of processing conditions on oil point pressure of *moringa oleifera* seed

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Abstract Seed oil expression is an important economic venture in rural Nigeria. The traditional techniques of carrying out the operation is not only energy sapping and time consuming but also wasteful. In order to reduce the tedium involved in the expression of oil from *moringa oleifera* seed and develop efficient equipment for carrying out the operation, the oil point pressure of the seed was determined under different processing conditions using a laboratory press. The processing conditions employed were moisture content (4.78, 6.00, 8.00 and 10.00 % wet basis), heating temperature (50, 70, 85 and 100 °C) and heating time (15, 20, 25 and 30 min). Results showed that the oil point pressure increased with increase in seed moisture content, but decreased with increase in heating temperature and heating time within the above ranges. Highest oil point pressure value of 1.1239 MPa was obtained at the processing conditions of 10.00 % moisture content, 50 °C heating temperature and 15 min heating time. The lowest oil point pressure obtained was 0.3164 MPa and it occurred at the moisture content of 4.78 %, heating temperature of 100 °C and heating time of 30 min. Analysis of Variance (ANOVA) showed that all the processing variables and their interactions had significant effect on the oil point pressure of *moringa oleifera* seed at 1 % level of significance. This was further demonstrated using Response Surface Methodology (RSM). Tukey's test and Duncan's Multiple Range Analysis successfully separated the means and a multiple regression equation was used to express the relationship existing between the oil point pressure of *moringa oleifera* seed and its moisture content, processing temperature, heating time and their interactions. The model yielded coefficients that enabled the oil point pressure of the seed to be predicted with very high coefficient of determination.

Keywords *Moringa oleifera* · Oil expression · Pressure · Crop processing · Nigeria

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Introduction

Moringa (*Moringa oleifera* Lam.) also known as horseradish or drumstick (Morton 1991), is a multipurpose tree crop in the semiarid region of North Eastern Nigeria. The plant produces fruits in form of lobbed pods that contain seeds with kernels having average protein and oil content of 27 and 42 %, respectively (Ram 1994). The seed therefore, serves as a good source of protein and cooking oil. The seed oil which is also known as ben oil finds application as raw material in the cosmetic industry and as lubricant for machineries. It burns without smoke and does not become rancid and sticky. The oil is also a possible source of biofuel (Sanford et al. 2009). The seed cake remaining after oil extraction can be used as fertilizer or as flocculent in water treatment. The seed and oil of moringa are used in the treatment of such ailments as arthritis, rheumatism, sexually transmitted diseases, hypertension and boils (Eilert et al. 1981). To obtain the seeds used in oil extraction, the pods are usually dried and shelled manually. The winged coatings on the seeds are then scraped or washed off and the brown and prism shaped seeds are collected. The seeds are further dehulled to obtain the kernels by pounding in a mortar using wooden pestle.

In the traditional process of oil extraction, the moringa seed kernels are subjected to a series of operations including roasting, grinding, heating the meal in a pan over an open fire or boiling it in a pot containing water. The above operations as presently carried out are not only labor intensive and time consuming, but also wasteful. As a result, there is the need to develop an appropriate technology and efficient oil expression system for the moringa seed.

Oil expression is a consolidation and compression process requiring the application of pressure. During the operation, reduction in volume occurs and causes the oil to seep out of the compressed seed (Sivala et al. 1991). The mechanics of oil seed expression of rapeseed was analyzed by Mrema and McNulty (1985) in relation to seed micro-structure, while Farabode and Favier (1997) analyzed it as a drained consolidation process in terms of stress–strain response of the seed bed and the dynamics of oil flow.

In Nigeria, small and medium scale processing of vegetable oil is mainly carried out using mechanical expression in preference to oil extraction using a solvent because expression is more economical (Tunde-Akintunde et al. 2001) and yields an end product that is free of dissolved chemicals, which makes it an inherently safer process (Khan and Hanna 1983). The pre-treatment operations that are known to influence oil yield in mechanical oil expression include heat treatment, moisture conditioning and size reduction (Khan and Hanna 1983; Adeeko and Ajibola 1990; Ajibola et al. 1993, 2000; Oyinlola and Adekoya 2004). Heat treatment of oil seed has been observed to rupture the oil bearing cells of the seed, coagulate the protein in the meal, adjust the moisture level of the meal to optimum level for oil expression, lower the viscosity and increase the fluidity of the oil to be expelled and destroy mould and bacteria thereby facilitating oil expression from the material (Adeeko and Ajibola 1990). Norris (1964) reported that size reduction, heat treatment and application of pressure are required for efficient oil expression from oil seeds with large particle sizes. Dedio and Dornell (1977) found that increasing the moisture content of flake seed from 8 to 16 % decreased the oil yield. The pressure at which oil comes out of the inter-particle voids of an oil seed is known as oil point pressure. It indicates the threshold pressure at which oil emerges from a seed kernel during mechanical oil expression (Ajibola et al. 2002). The oil point pressure determines the effectiveness of an expression operation because subsequent flow and yield of oil are triggered by pressure applied beyond the oil point pressure (Olatunde and Owolarafe 2011).

Several researchers have studied the effect of processing parameters on the oil point pressure of oil seeds. These include investigations on the oil point pressure of rape seed (Sukumaran and Singh 1989), sesame seed (Ajibola et al. 2000), soyabean (Ajibola et al. 2002), locust bean (Owolarafe et al. 2003), cashew kernels (Ogunshina et al. 2008), melon seeds (Tunde-Akintunde 2010), neem seed (Olatunde and Owolarafe 2011) and Indian almond kernels (Aregbesola et al. 2012). Studies on the oil point pressure of *moringa oleifera* seed appear not to have been carried out. The optimal condition at which the oil point pressure of the seed is identified will improve the oil expression efficiency and provide useful information for the design and performance evaluation of moringa seed oil expeller. The objective of this study, therefore, was to determine the oil point pressure of *moringa oleifera* seed and investigate the effect of such processing parameters as moisture content, heating temperature and heating time on the oil point pressure.

Materials and methods

Material procurement and preparation

The *moringa oleifera* seeds used in this study were bought from a market in Numan, a town in Adamawa State, Nigeria. The seeds were cleaned and sorted to remove foreign materials and broken or immature seeds. They were then shelled to obtain the kernels which were then sun dried to prevent fungal attack, and packaged in sealed polyethylene bags.

Moisture content determination and adjustment

The initial moisture content of the seed kernels was determined using the oven method. 10 g of seeds were taken in triplicates and oven dried at 130 °C for 6 h (AOAC 1990). The average value of moisture content was calculated and recorded.

Samples of seed kernels at the initial moisture content were conditioned to three different moisture levels in % wet basis using the method adopted by Owolarafe et al. (2003). This involved the addition of calculated amount of water to a sample at the initial moisture content to raise it to the desired moisture content. The samples at different moisture levels were sealed in labelled polyethylene bags and kept in a freezer under a temperature of 10 °C for 48 h. This enabled the samples to attain stable and uniform moisture contents.

Heat treatment and duration

Samples of *moringa oleifera* seed kernels at different moisture contents in sample trays were heated in an oven at the

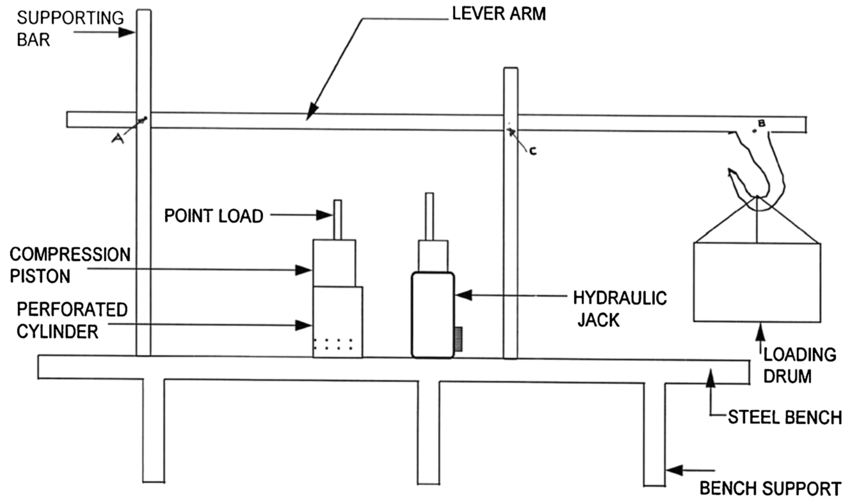

Fig. 1 Laboratory oil expression press

temperatures of 50, 70, 85 and 100 °C respectively, each for the durations of 15, 20, 25 and 30 min.

Oil point pressure determination

The oil point pressure of *moringa oleifera* seeds was identified using the method that was applied by Ajibola et al. (2002) on soyabean, Owolarafe et al. (2003) on locust bean and Tunde-Akintunde (2010) on melon seeds. The schematic diagram of the laboratory press used is shown in Fig. 1. It consists of a loading drum attached to the end of a lever arm. The lever arm is graduated from 0 cm at the support to 300 cm at its end. A known weight is placed in the drum to generate certain levels of pressure at different positions along the lever arm. The load on the drum was fixed and the position of a point load can be varied along the length of the lever arm. The point load was attached to a compression metal disk to form the rod and piston together supported by a pressing cylinder. The load was transferred by lowering the lever arm to make contact with the rod of the point load. The cylinder which is 40 mm in diameter and 50 mm in height is made of mild steel pipe and welded to a metal plate that serves as the base for the pressing cylinder. Holes (3 mm in diameter) were drilled in the section of the

Table 1 Oil point pressure of moringa oleifera seed at different moisture contents, temperatures and heating times

Heating temperature, (°C)	Heating time, (Min)	Moisture content, (%)			
		4.78 Oil point pressure (Mpa)	6.00	8.00	10.00
50	15	0.4153	0.4882	0.6464	1.1239
	20	0.4014	0.4626	0.6259	0.8997
	25	0.3953	0.4497	0.6258	0.8231
	30	0.3925	0.4455	0.6069	0.7882
70	15	0.3881	0.4552	0.6259	0.8318
	20	0.3854	0.4499	0.6057	0.7359
	25	0.3733	0.4437	0.4779	0.6750
	30	0.3604	0.4369	0.4593	0.6743
85	15	0.3560	0.4462	0.5889	0.7319
	20	0.3417	0.4398	0.4587	0.6953
	25	0.3366	0.4369	0.4421	0.6799
	30	0.3317	0.4198	0.4370	0.6555
100	15	0.3436	0.4410	0.4255	0.6528
	20	0.3320	0.4350	0.4130	0.6387
	25	0.3242	0.4249	0.4035	0.6273
	30	0.3164	0.4162	0.3891	0.5934

Table 2 ANOVA of moringa oleifera seed oil point pressure with processing conditions

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5.032[a]	63	0.080	4,771.999	0.000	1.000
Intercept	50.547	1	50.547	3,019,899.238	0.000	1.000
M	3.629	3	1.210	72,276.914	0.000	0.999
T	0.629	3	0.210	12,518.362	0.000	0.997
t	0.198	3	0.066	3,944.539	0.000	0.989
M * T	0.316	9	0.035	2,099.768	0.000	0.993
M * t	0.117	9	0.013	777.589	0.000	0.982
T * t	0.025	9	0.003	164.783	0.000	0.921
M * T * t	0.118	27	0.004	260.637	0.000	0.982
Error	0.002	128	1.674E-5			
Total	55.581	192				
Corrected Total	5.034	191				

Dependent variable: P, R Squared=1.000 (Adjusted R Squared=0.999), M=moisture content (%), T=temperature (°C), t=heating time (minutes)

metal plate covering the pressing cylinder into which tissue papers were inserted prior to the pressing operation. A hydraulic jack was used to lower and lift the lever arm at the beginning and end of the pressing process.

To carry out a pressing operation, the cylinder, with strips of tissue paper fitted in place, was filled with moringa seed kernels at known moisture content, heating temperature and duration of heating and placed under the compression piston. The lever arm was raised with the hydraulic jack and the cylinder and compression piston were brought under the lever arm. The jack was slowly released to allow the lever arm to rest totally on the piston. Pressure was then transferred through the piston to the seed kernels and after the pressing operation, the jack was used to lift the lever arm and the strips of tissue papers were checked for oil marks. If there are oil stains on the tissue, then the oil point pressure is taken to have been reached. If there is no oil stain then the experiment is repeated with a reduction in distance between the lever support and the cylinder position. If the oil stains are much, then the experiment is repeated with increase in the distance between the support and cylinder position. The distance from the point where the compression piston touched the lever arm was measured and converted to pressure using the principle of moment of forces. The experiment was replicated thrice and the average values of oil point pressure were calculated.

Statistical analysis

The data obtained was subjected to Analysis of Variance (ANOVA) in a completely randomised factorial design

Table 3 Multiple range comparison of moringa oleifera seed oil point pressure with respect to moisture content

M		N	Subset			
			1	2	3	4
Tukey HSD[a,b]	4.7800	48	0.36152708			
	6.0000	48		0.44286667		
	8.0000	48			0.51648958	
	10.0000	48				0.73148333
	Sig.		1.000	1.000	1.000	1.000
Duncan[a,b]	4.7800	48	0.36152708			
	6.0000	48		0.44286667		
	8.0000	48			0.51648958	
	10.0000	48				0.73148333
	Sig.		1.000	1.000	1.000	1.000

Table 4 Multiple range comparison of moringa oleifera seed oil point pressure with respect to heating temperature

	T	N	Subset			
			1	2	3	4
Tukey HSD[a,b]	100	48	0.44307083			
	85	48		0.48697292		
	70	48			0.52315417	
	50	48				0.59916875
	Sig.		1.000	1.000	1.000	1.000
Duncan[a,b]	100	48	0.44307083			
	85	48		0.48697292		
	70	48			0.52315417	
	50	48				0.59916875
	Sig.		1.000	1.000	1.000	1.000

using SPSS for Windows version16. Comparison of means was carried out using Tukey's test and Duncan's Multiple Range Analysis at the 95 % confidence level. Response Surface Methodology was applied using the Design Expert software and multiple regression analysis was conducted to establish the model that expresses the relationship existing between the oil point pressure of *moringa oleifera* seed and processing parameters.

Results and discussion

The average oil point pressures obtained for *moringa oleifera* seeds at different moisture contents, heating temperatures and heating times are presented in Table 1. From this table, it can be seen that within the ranges of processing conditions studied, the oil point pressure ranged from 0.3164 Mpa at the moisture content, heating temperature and heating time of 4.78 %, 100 °C and 30 mins to 1.1239 Mpa at the moisture content of 10 %, heating temperature of 50 °C and heating time of 15 mins. The result of ANOVA presented in Table 2 shows that the processing conditions of moisture content, heating temperature and heating time had significant effect on the oil point pressure at 1 % level of significance.

The Tukey and Duncan separation of mean oil point pressure with respect to moisture content, heating temperature and heating time, are shown in Tables 3, 4 and 5 respectively.

The oil point pressure of *moringa oleifera* seeds increased with increase in moisture content (Table 3) and was in agreement with the findings of other investigators: Sukumaran and

Table 5 Multiple range comparison of moringa oleifera seed oil point pressure with respect to heating time

	t	N	Subset			
			1	2	3	4
Tukey HSD[a,b]	30	48	0.47544583			
	25	48		0.49553542		
	20	48			0.51974792	
	15	48				0.56163750
	Sig.		1.000	1.000	1.000	1.000
Duncan[a,b]	30	48	0.47544583			
	25	48		0.49553542		
	20	48			0.51974792	
	15	48				0.56163750
	Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed, based on observed means

Error term is Mean Square(Error)=1.67E-005

[a] Uses harmonic mean sample size=48.000

[b] Alpha=0.05

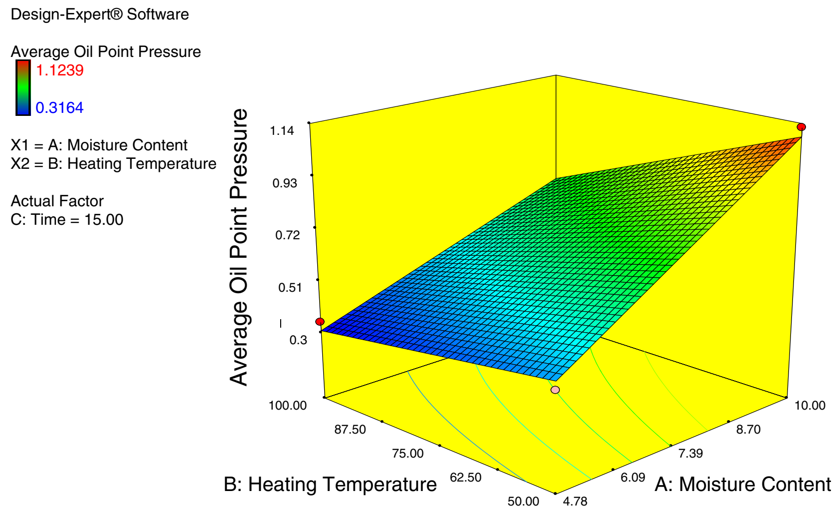

Fig. 2 Response surfaceof oil point pressure of moringa oleifera seed with moisture content and heating temperature at the heating time of 15 mins

Singh (1989), Ajibola et al. (2002), Owolarafe et al. (2003), Ogunshina et al. (2008), Tunde-Akintunde (2010) and Aregbesola et al. (2012) on rape seed, soya bean, locust bean, cashew nut, melon seeds and Indian almond kernels, respectively. This result could be due to the cushioning effect of mucilage developed at higher moisture levels. The mucilage must have consumed some of the energy generated by pressure applied during the compression of the material to force the oil out of the cells, thereby increasing the oil point pressure (Ajibola et al. 2002; Tunde-Akintunde 2010).

Oil point pressure decreased with increase in heating temperature and heating time (Tables 4 and 5). The decrease in oil point pressure with increase in heat treatment is probably due to the fact that heating for long periods results in moisture adjustment (Olatunde and Owolarafe 2011), reduction of viscosity, which enabled the oil to flow easier from the cell structure (Tunde-Akintunde 2010) and protein coagulation which is one of the factors necessary for oil expression (Khan and Hanna 1983; Adeeko and Ajibola 1990).

The interactive effects of moisture content and heating temperature (M*T), moisture content and heating time (M*t), heating temperature and heating time (T*t) as well as moisture content, heating temperature and heating time (M*T*t) (Table 2) on the oil point pressure, were significant at 1 % level of significance. The response of oil point pressure to moisture content and heating temperature variation at the heating time of 15 min is presented in Fig. 2. The Figure reveals that the oil point pressure of moringa seeds increased with increase in moisture content and decreased with increase in heating temperature at constant heating time. Similar trend of oil point pressure with moisture content and heating temperature to that which is shown in Fig. 2 was exhibited by the seeds at the heating times of 20, 25 and 30 min.

The response of oil point pressure to moisture content and heating time variation at the heating temperature of 50 °C (Fig. 3) reveals that it increased with increase in moisture content but decreased with increase in heating time at constant

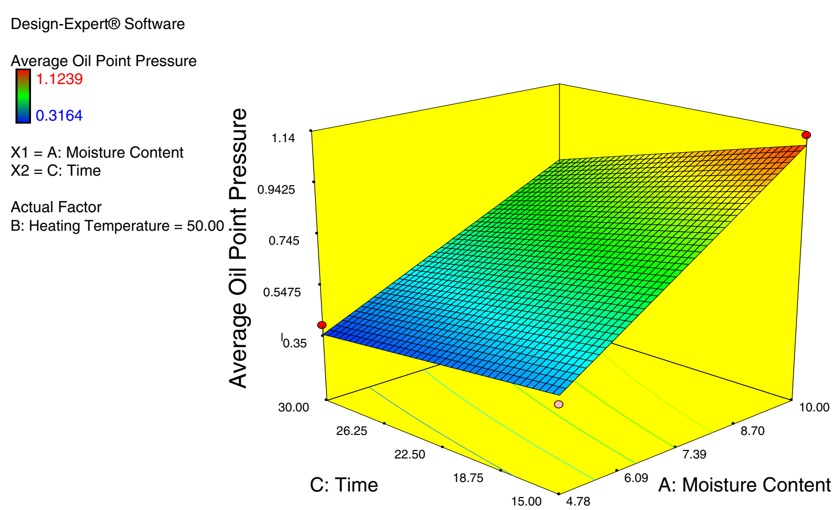

Fig. 3 Response surfaceof oil point pressure of moringa oleifera seed with moisture content and heating time at the heating temperature of 50 °C

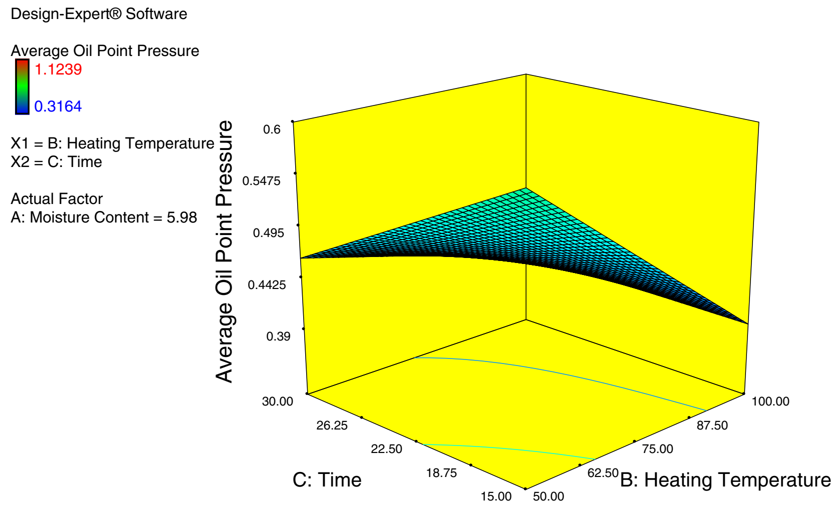

Fig. 4 Response surfaceof oil point pressure of moringa oleifera seed with heating temperature and time at the moisture content of 6.00 %

heating temperature. At the heating temperatures of 70, 85 and 100 °C, the oil point pressure of moringa seeds exhibited similar trend with moisture content and heating time to the one obtained at 50 °C. The response of oil point pressure to heating temperature and time at the moisture content of 6 % (Fig. 4) shows that it decreased with increase in heating temperature and heating time. Similar trend to the one obtained at 6 % moisture content was exhibited by the oil point pressure at the moisture contents of 5, 8 and 10 %, respectively.

The result of multiple regression analysis carried out to express the oil point pressure (P) as a function of the processing parameters of moisture content (M), heating temperature (T), heating time (t) is presented in Table 6. From this Table, it can be seen that the analysis yielded coefficients with which the function that can be used to adequately predict the oil point pressure of *moringa oleifera* seed on the basis of processing parameters was established. The model (Eq. 1) is expressed as follows:

$$\begin{aligned} P = & -0.348 + 0.151M + 0.009T \\ & + 0.024t - 0.002MT - 0.007Mt + 6.444 \times 10^{-5}MTt \\ & + 0.009M^2 + 2.038 \times 10^{-5}T^2 \; R^2 \\ = & \; 0.95 \end{aligned} \qquad (1)$$

A *t*-test of coefficients showed that the constant, T, t and T^2 terms did not make statistically significant contribution to the predictive function of the equation. The M, MT, Mt and M^2 terms however, made significant contribution to the equation at 1 % level of significance. This model can be used to

Table 6 Coefficients for the regression analysis on oil point pressure of moringa oleifera seeds

Model	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	−0.348	0.365		−0.954	0.344
M	0.151	0.051	1.854	2.974	0.004
T	0.009	0.005	0.998	1.770	0.082
t	0.024	0.017	0.816	1.413	0.164
MT	−0.002	0.001	−2.976	−4.198	0.000
Mt	−0.007	0.002	−2.517	−3.516	0.001
Tt	0.000	0.000	−1.369	−2.033	0.047
MTt	6.444E-5	0.000	2.245	2.661	0.010
M^2	0.009	0.002	1.680	5.344	0.000
T^2	2.038E-5	0.000	0.349	1.157	0.253
t^2	0.000	0.000	0.413	1.332	0.189

[a] Dependent Variable: P

optimize the moringa seed oil expression process and to design and control the oil expression equipment.

The oil point pressure of moringa oleifera seeds is lower than that of sesame seed (Ajibola et al. 2000), soya bean (Ajibola et al. 2002), melon seed (Tunde-Akintunde 2010), sunflower (Rusinek et al. 2012), locust bean (Owolarafe et al. 2003) and Indian almond kernels (Aregbesola et al. 2012), and higher than that of cashew kernels (Ogunshina et al. 2008). At moisture contents below 8 %, the oil point pressure of moringa seeds was lower than that of neem seed (Olatunde and Owolarafe 2011) and thereafter, it became with further increase in moisture content.

Conclusions

This study revealed that the oil point pressure of *moringa oleifera* seeds is affected by moisture content, heating temperature and heating time. The oil point pressure of the seed increased with increase in moisture content and decreased with increase in heating temperature and heating time. It ranged from 0.3164 Mpa at the moisture content, heating temperature and heating time of 4.78 %, 100 °C and 30 mins to 1.1239 Mpa at the moisture content of 10 %, heating temperature of 50 °C and heating time of 15 mins. The relationship existing between the oil point pressure and processing parameters was adequately expressed by a multiple regression model. The model yielded coefficients that are significant, and it is useable in the optimization and control of moringa seed oil expression process.

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