

# Effect of processing parameters on the expression efficiency of almond oil in a mechanical expression rig

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**Abstract:** The process parameters that can affect the expression efficiency of a mechanical expression rig (MER) for almond kernel (*Terminalia catappa*) were investigated in an optimization study using central composite design (CCD). A four factor, five levels of CCD was applied to study the effect of moisture content (6%-10% wb), temperature (80°C-100°C), heating time (10-26 min.) and applied pressure (5.84-7.01 MPa) using the chosen range. The physico-chemical properties of the expressed almond oil were also determined using standard procedure. The results of the study showed that all the variables significantly affected the expression efficiency at 95% confidence level. The optimum expression efficiency of 76.35% was obtained at temperature, pressure, heating time and moisture content of 93.34°C, 6.44 MPa, 17.16 minutes and 8.71% wb, respectively. This indicates that the MER performed satisfactorily. The experimental values were very close to the predicted values with  $p < 0.05$ . The regression model obtained has provided a basis for selecting optimal process parameters for the recovery of oil from almond kernel using the MER. The physico-chemical properties investigated showed that refractive index, viscosity, saponification value, iodine value, free fatty acid value, acid value, peroxide value, flash, and fire points are within the range suitable for many purposes as it showed that it was edible and conformed to CODEX standard for edible oil.

**Keywords:** almond seeds, mechanical expression, expression efficiency, central composite design

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## 1 Introduction

Almond tree is one of the versatile tree nuts, perennial in nature, usually grown within the cold and temperate regions mainly as shade during hot weather or as orchard crop or for ornamental purposes (Agatemor, 2006; Agunbiade and Olanlokun, 2006; Apata, 2011; Young et al., 2004; Mirzabe et al., 2013; Nwosu et al., 2008). Almond, a very fruitful tree that has nut which contains high quality oil that is light-weight and

golden-brown colour, which has natural remedy for many diseases. The oil is non-drying and edible, which is largely used in manufacturing industries such as pharmaceuticals, cosmetics, soap making, medicinal and so on (Sheikh et al., 2013). Almond oil is a good antioxidant (Adu et al., 2013). Among other useful content of almonds are dietary fibre, health promoting unsaturated fatty acids, vitamin E, other vitamins, minerals. It is low in saturated fats and contains no cholesterol. The alpha-tocopherol was the most prevalent tocopherol except in walnuts (Maguire et al., 2004; Yildirim and Kostem, 2014). Due to these enormous contents, almonds have a great significant economic importance, with low content of sugar useful as diet for diabetics. It reduces colon cancer and cardiovascular risk

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(Passey and GrosLouis, 1993). However, despite these noble uses of almond oil, little work has been reported on its expression from kernel.

So far, supercritical CO<sub>2</sub> extraction is the only method reported in the literature for almond oil (Marrone et al., 1998). Therefore, other methods of expression can be studied. Solvent extraction using n-hexane has been widely used in lipid extraction, which can achieve almost complete recovery of oil from a sample matrix. However, unsafe handling of n-hexane and its unacceptability for food purpose, as it is harmful to human health and the environment, restrict its use in the food, cosmetic and pharmaceutical industries, hence the need for industries to search for alternative processing methods (Akanda et al., 2012; Liu et al., 2009). Therefore, mechanical expression is seen as a more favourable alternative to solvents extraction of lipids and meets the growing demand for safe natural lipids of excellent quality.

Mechanical expression involves direct application of forces to vegetable kernels in order to get oil out of it (Adejumo et al., 2013). This expression procedure includes different types of press such as hydraulic press, screw press and rolling press (Deli et al., 2011). It is more suitable for small, medium and large (commercial) capacity operations, which may be due to the fact it is economical compared with the other expression methods (Orhevba et al., 2013). Meanwhile, pre-treatments and operating conditions determine the expression efficiency of mechanical extraction. Therefore, this study investigates the effect of some pre-treatments on the expression efficiency.

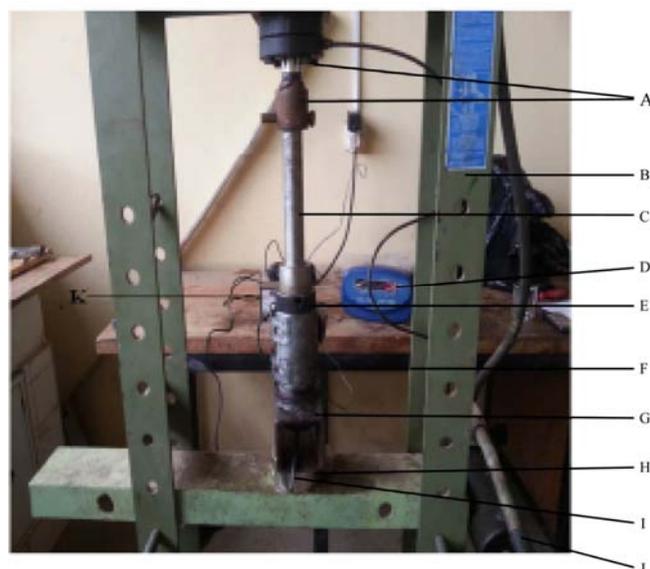
The aim of this study is to evaluate the effect of temperature, heating duration, applied pressure, and moisture content on the expression efficiency of mechanical expression rig in an optimisation study using central composite design (CCD) of response surface methodology (RSM) for almond kernel. The expressed almond oil was characterized to determine the effect of the expression method on its quality.

## 2 Materials and methods

### 2.1 Description of the mechanical expression rig (MER)

The MER that was used in this study was developed

at National Centre for Agricultural Mechanization (NCAM), Ilorin, Nigeria. It consists of a piston-cylinder rig in conjunction with hydraulic press and load cell. The piston-cylinder rig is made up of a compression piston, a press cage cylinder, a supporting platform and an oil collecting pan. The piston serves as the pressing ram and it distributes pressure from the hydraulic press evenly on the oilseed sample in the press cage cylinder. A 605 W electric band heater was installed to enfold the press cage cylinder and hence serves as a heating device for mechanical expression process. The rig is adequately instrumented with a temperature transducer to control the temperature while the pressure for expression is obtained from the digital force measuring device.



A- Plunger, B- Frame, C- Compression piston, D- Digital force measuring device, E- Press cage cylinder, F- Heating band, G- Support platform, H- Load cell, I- Hydraulic press handle, J- Temperature controller

Figure 1 Pictorial view of the mechanical oil rig

### 2.2 Almond seed preparation

The almond fruits used in this study were gathered from some South-East states of Nigeria (Imo and Anambra state) where there are clusters of the trees as it is not sold in Nigeria market. The fruit was cleaned, peeled and manually cracked. The moisture content was determined using standard method of Association of Official Analytical Chemists (AOAC, 1990). The prepared kernel of 100 g was weighed, oven dried at 130°C for 6 h and cooled in a desiccator. The kernel size was reduced by motorized attrition mill and screened to coarse particle size of  $\Phi \geq 2$  mm using manual sieve. The kernel was further divided into five samples and

conditioned to moisture content of 6%, 7%, 8%, 9% and 10% wb by adding the required quantity of distilled water. The conditioned samples were sealed in polyethylene bags and stored in the freezer for 48 h, to allow for even distribution of the moisture.

### 2.3 Experimental design and statistical analysis

A four factor, five levels of CCD in RSM of design expert version 8.0.1 was employed for this study with parameters such as temperature ( $^{\circ}\text{C}$ ), pressure (MPa), heating time (min) and moisture content (% wb) coded as  $X_1$ ,  $X_2$ ,  $X_3$ , and  $X_4$  respectively. The levels are differentiated by their different values. The levels of the parameters were chosen based on literature findings and preliminary study as shown in Table 1.

**Table 1 Process parameters and their levels using CCD of RSM**

Parameters	Coded symbol and unit	Levels				
Temperature	$X_1$ ( $^{\circ}\text{C}$ )	80	85	90	95	100
Pressure	$X_2$ (MPa)	5.84	6.14	6.43	6.72	7.01
Heating time	$X_3$ (min)	10	14	18	22	26
Moisture content	$X_4$ (% wet basis)	6	7	8	9	10

The experimental results obtained were analyzed using quadratic polynomial equation of the form stated in Equation (1) as generated by the design expert. The quality of the fit of the model was evaluated using analysis of variance (ANOVA).

$$Y = \beta_0 + \sum_{i=1}^n \beta_i x_i + \sum_{i=1}^n \beta_{ii} x_i^2 + \sum_{i=1}^{n-1} \sum_{j=i+1}^n \beta_{ij} x_i x_j \quad (1)$$

where,  $Y$  represents the predicted response;  $\beta_0$  is the offset term;  $\beta_i$  is the linear coefficient;  $\beta_{ii}$  is the second-order coefficient and  $\beta_{ij}$  is the interaction coefficient;  $x_i$  and  $x_j$  are the independent variables.

### 2.4 Almond oil expression efficiency procedure

The 80 g of the conditioned almond kernel sample with moisture content of 6% (wb) was measured into the press cage cylinder and heated at  $80^{\circ}\text{C}$  for 10 min. The pressure was gradually applied manually through the hydraulic press and the compression piston distributes pressure on the kernel sample in the cylinder. The almond kernel thereby released the oil which flows through the mesh into the oil collector. The applied pressure was measured by digital force measuring unit through the load cell data cable connected to it. The press cage cylinder was dismantled and the residual cake was extruded. The

process was repeated for the various ranges of parameters. The expression efficiency and process loss was determined using the equations given by Adejumo et al. (2013) and Olaniyan and Oje (2007) as stated in Equations (2) and (3), respectively:

$$\% \text{ Expression efficiency (EE)} = \frac{W_{oe}}{W_t} \times 100 \quad (2)$$

$$\% \text{ Process loss (PL)} = \frac{W_{us} - (W_{rc} + W_{oe})}{W_{cs}} \quad (3)$$

where,  $W_{cs}$  = weight of crushed almond seed sample, g;  $W_{oe}$  = weight of oil expressed, g;  $W_{cs}$  = weight of crushed almond seed sample, g;  $W_{rc}$  = weight of residual cake after expression, g;  $W_{oe}$  = weight of oil expressed, g.

### 2.5 Physico-chemical characteristics of almond oil

The expressed oil samples from the almond kernel obtained at different pre-treatment conditions were characterized to determine their physico-chemical properties such as, acid value (AV), iodine value (IV), saponification values (SV), peroxide value (PV), refractive index (RI), free fatty acid (FFA), viscosity (V), flash point (FLP), fire point (FIP), colour and pH using the procedures described by International Union of Pure and Applied Chemistry Commission on Oils, Fats and Derivatives (IUPAC, 1987) except for pH that was determined using the method described by Dagnachew et al. (2015).

## 3 Result and discussion

### 3.1 Expression efficiency of almond oil

The result of the experiment is shown in Table 2. The individual, interactive and quadratic effects of the parameters on the expression efficiency were evaluated. The ANOVA result obtained is shown in Table 3. From the ANOVA, the individual, interactive and quadratic effects show significant effect with  $p$  value  $< 0.05$ . However, the interaction between temperature and moisture content ( $X_1 X_4$ ) and pressure and heating time ( $X_2 X_3$ ) were insignificant. The  $F$ -values also indicate the order of significance of the parameters giving moisture content as the most important parameter that affected the expression efficiency followed by temperature, applied pressure and heating time.

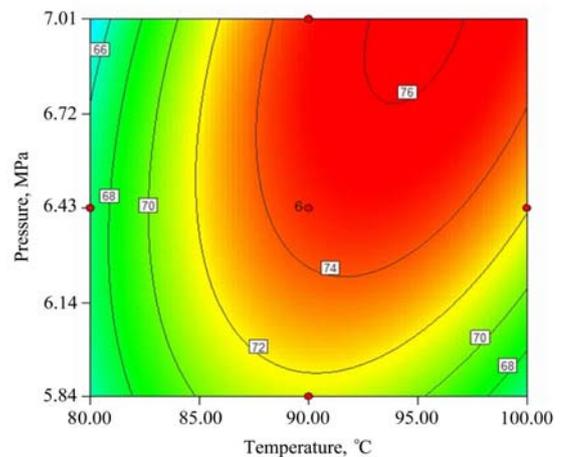
**Table 2 Experimental design matrix and results for the expression efficiency**

Run	Process parameters				Expression efficiency (EE %)		
	X <sub>1</sub> , °C	X <sub>2</sub> , MPa	X <sub>3</sub> , min	X <sub>4</sub> , % wb	Actual	Predicted	Residual
1	85	6.14	14	7	61.52	61.360	0.160
2	95	6.14	14	7	64.56	64.870	-0.310
3	85	6.72	14	7	64.68	64.698	-0.018
4	95	6.72	14	7	70.51	70.754	-0.244
5	85	6.14	22	7	65.14	65.077	0.063
6	95	6.14	22	7	63.06	63.458	-0.398
7	85	6.72	22	7	68.61	68.516	0.094
8	95	6.72	22	7	69.11	69.441	-0.331
9	85	6.14	14	9	70.94	70.879	0.061
10	95	6.14	14	9	74.81	75.150	-0.340
11	85	6.72	14	9	68.61	68.457	0.153
12	95	6.72	14	9	74.94	75.273	-0.333
13	85	6.14	22	9	71.14	71.141	-0.001
14	95	6.14	22	9	70.03	70.282	-0.252
15	85	6.72	22	9	68.86	68.820	0.040
16	95	6.72	22	9	70.10	70.506	-0.406
17	80	6.43	18	8	66.38	66.914	-0.534
18	100	6.43	18	8	73.16	72.111	1.049
19	90	5.84	18	8	71.67	71.422	0.248
20	90	7.01	18	8	75.22	74.962	0.258
21	90	6.43	10	8	64.94	64.762	0.177
22	90	6.43	26	8	64.05	63.712	0.338
23	90	6.43	18	6	62.66	62.426	0.234
24	90	6.43	18	10	73.29	73.009	0.281
25	90	6.43	18	8	75.19	74.704	0.486
26	90	6.43	18	8	73.42	74.704	-1.284
27	90	6.43	18	8	74.94	74.704	0.236
28	90	6.43	18	8	75.19	74.704	0.486
29	90	6.43	18	8	74.68	74.704	-0.024
30	90	6.43	18	8	74.81	74.704	0.106

**Table 3 ANOVA for expression efficiency of MER for almond oil**

Source	Sum of squares	Df	Mean square	F-Value	P-Value Prob>F
X <sub>1</sub>	40.510	1	40.508	123.307	0.000000*
X <sub>2</sub>	19.138	1	19.138	58.255	0.000002*
X <sub>3</sub>	1.654	1	1.654	5.034	0.040376*
X <sub>4</sub>	168.010	1	168.010	511.426	0.000000*
X <sub>1</sub> X <sub>2</sub>	6.477	1	6.477	19.716	0.000477*
X <sub>1</sub> X <sub>3</sub>	26.317	1	26.317	80.109	0.000000*
X <sub>1</sub> X <sub>4</sub>	0.578	1	0.578	1.758	0.204685**
X <sub>2</sub> X <sub>3</sub>	0.010	1	0.010	0.030	0.863828**
X <sub>2</sub> X <sub>4</sub>	33.178	1	33.178	100.993	0.000000*
X <sub>3</sub> X <sub>4</sub>	11.937	1	11.937	36.337	0.000023*
X <sub>1</sub> <sup>2</sup>	46.157	1	46.157	140.503	0.000000*
X <sub>2</sub> <sup>2</sup>	3.975	1	3.975	12.099	0.003370*
X <sub>3</sub> <sup>2</sup>	187.626	1	187.626	571.137	0.000000*
X <sub>4</sub> <sup>2</sup>	83.597	1	83.597	254.471	0.000000*
Error (Residual)	4.928	15	0.328		
Total SS	570.907	29			

Figure 2 shows the interaction effect of pressure and temperature on expression efficiency. Expression efficiency increases with pressure at constant temperature, heating time and moisture content. It is also observed that the efficiency decrease or level off as the pressure increases from 6.72 to 7.01 MPa. This observation may be due to the blocking of oil path between some inter-kernel voids, because of compaction of particles which results to low yield thereby leading to decrease in expression efficiency.



Note: Where ‘\*’ denotes those factors significant at 5% confidence level, while ‘\*\*’ denotes insignificant terms.

Figure 2 Response surface plot showing the combined effect of interaction of pressure and temperature on expression efficiency

This temperature trend is in agreement with previous works which attribute this behavior of oilseed to the fact that heat coagulates the protein and reduces the viscosity of the oil thereby facilitating oil expression process as moisture reduction takes place simultaneously. At higher temperature, prolonged heat treatment causes a substantial moisture loss leading to hardening of oil seed sample which best explains the reason behind the reduction in yield at higher temperature (Alonge et al., 2003; Akubude et al., 2017; Bangboye and Adejumo, 2011; Ajibola 1993) which resulted to decrease in expression efficiency.

Figure 3 shows the interaction effect of heating time and temperature on expression efficiency. Increase in temperature and heating time favours expression efficiency as pressure and moisture content are held constant. High expression efficiency of 73.16% and 64.05% were obtained at high temperature of 100°C and heating time of 26 minutes, respectively while low

expression efficiency of 66.38% and 64.94% were obtained at low temperature of 80°C and heating time of 10 minutes, respectively at constant pressure of 6.43 MPa and moisture content of 8% wb.

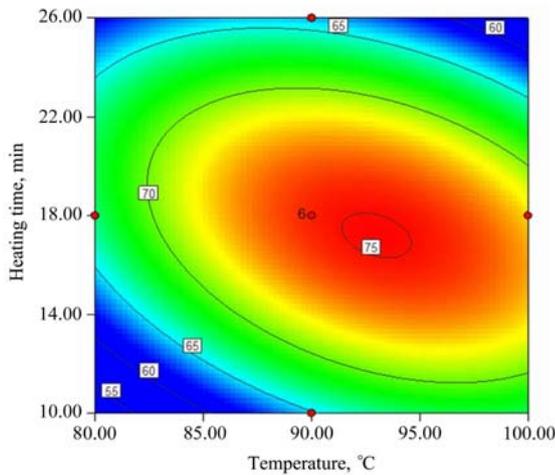


Figure 3 Response surface plot showing the combined effect of interaction of heating time and temperature on expression efficiency

Figure 4 shows the interaction effect of moisture content and temperature on expression efficiency. Expression efficiency increases with increase in moisture content and temperature at constant pressure and heating time. At pressure of 6.43 MPa and heating time of 18 minutes, expression efficiency increased from 62.66% to 75.19% as moisture content increased from 6% wb to 8% wb but reduces as moisture content increases to 10% wb. Low expression efficiency of 66.38% was obtained at 80°C and high expression efficiency of 73.16% at 100°C as shown in Table 2.

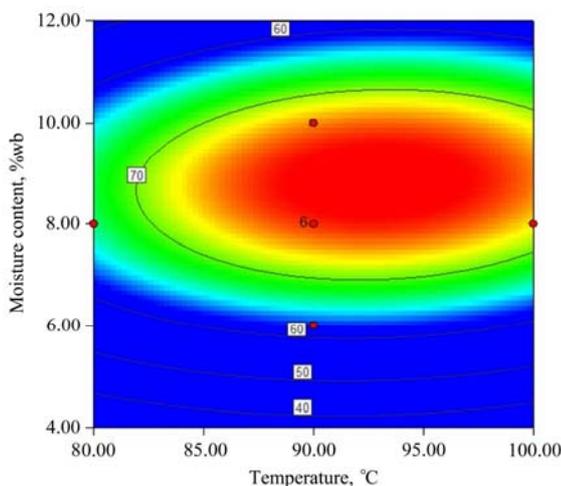


Figure 4 Response surface plot showing the combined effect of interaction of moisture content and temperature on expression efficiency

Figure 5 shows the interaction effect of heating time and pressure on expression efficiency. Expression efficiency decreases from 64.94% to 64.05% as heating time increases from 10 minutes to 26 minutes but increases from 71.67% to 75.22% as pressure increases from 5.84 MPa to 7.01 MPa as shown in Table 2.

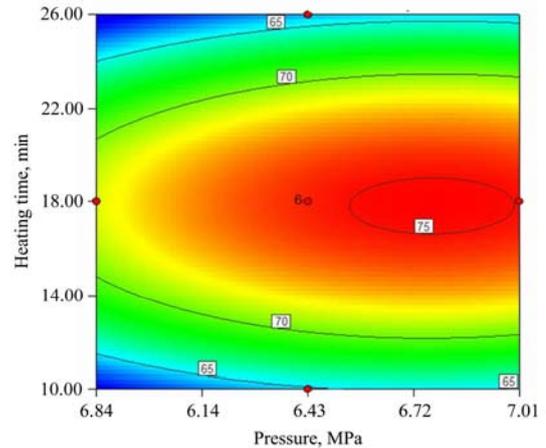


Figure 5 Response surface plot showing the combined effect of interaction of heating time and pressure on expression efficiency

Figure 6 shows the interaction effect of moisture content and pressure on expression efficiency. The expression efficiency increases as moisture content and pressure increases but reduces as moisture content is further increased. And Table 2 further shows that increase in moisture content from 8% wb to 10% wb results in decrease in expression efficiency from 75.19% to 73.29%.

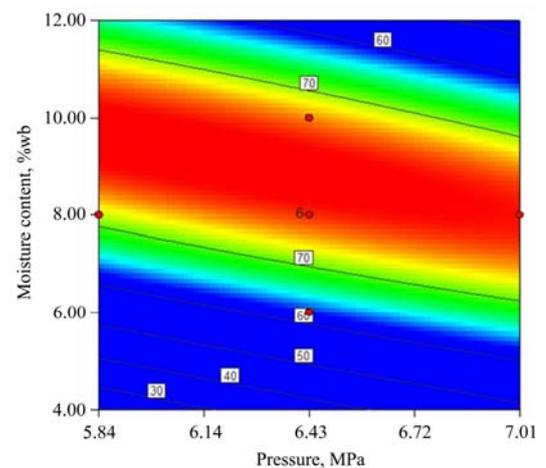


Figure 6 Response surface plot showing the combined effect of interaction of moisture content and pressure on expression efficiency

Figure 7 shows the interaction effect of moisture content and heating time on expression of efficiency. As moisture content increases from 6% wb to 8% wb,

expression efficiency increases from 62.66% to 75.19% but reduces to 73.29 % as the moisture content increases to 10% wb. But high expression efficiency of 64.94% was obtained at low heating time of 10 minutes and low expression efficiency of 64.05% was obtained at high heating time of 26 minutes. Although, the difference between the two expression efficiency is quite small (0.89%), but it is an indicator that low heating time favours more oil yield and hence high expression efficiency.

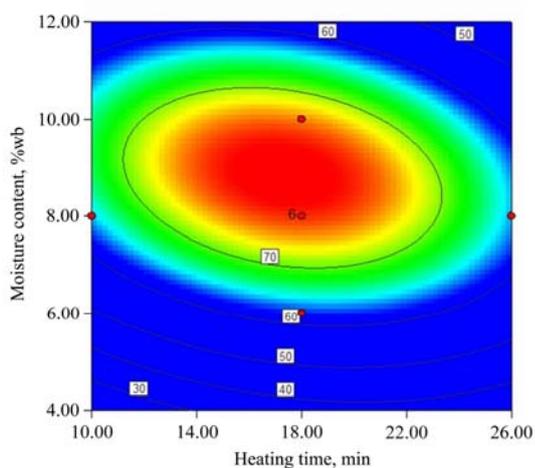


Figure 7 Response surface plot showing the combined effect of interaction of moisture content and heating time on expression efficiency

### 3.2 Regression model and optimization

The regression model developed using design expert is given as:

$$Y_3 (\%) = 74.70 + 2.60X_1 + 1.78X_2 - 0.53X_3 + 5.29X_4 + 1.27X_1X_2 - 2.56X_1X_3 - 2.88X_2X_4 - 1.73X_3X_4 - 2.60X_1^2 - 0.75X_2^2 - 5.23X_3^2 - 3.49X_4^2$$

$$(R^2 = 0.991 \text{ and adjusted, } R^2 = 0.983)$$

The correlation coefficient ( $R$ -squared) of the model analysis was found to be 0.991. The model above was used to make predictions as shown in Table 2. The actual value and predicted values are not statistically different at  $p < 0.05$ . Hence, making the model fit for making prediction.

Through numerical optimization, the optimum parameters for optimum expression efficiency of 76.35% was obtained at temperature, pressure, heating time and moisture content of 93.34°C, 6.44 MPa, 17.16 min and 8.71% wb, respectively.

### 3.3 Physio-chemical properties of oil

The result of both chemical and physical quality

parameters of the oil samples produced are shown in Table 4.

#### 3.3.1 Acid value

This ranges from 1.009 to 2.693 mg/NaOH/g within the range of process parameters used as shown in Table 4. The range of values for acid value is within the range of values given as standard for edible oils as 0.6-10 mg/KOH/g (CODEXSTAN, 1999). Acid value is a pointer to the edibility of oils and quality of fatty acids in oils which serves as an indicator to the presence and extent of hydrolysis by lipolytic enzymes and oxidation.

The low acid value assures the oil stability and protection against rancidity and peroxidation (Aremu et al., 2015). Hence, almond oil is suitable for cooking but not for liquid soap, shampoos and paint production because of its low acid value.

#### 3.3.2 Free fatty acid value

From Table 4, free fatty acid value ranges from 0.505 to 1.346 mg/NaOH. This is within the range given in literature as 0.39-20.05 mg/NaOH/g for almond oil (Aremu et al., 2015). FFA is a key feature linked with the quality and commercial value of oils and fats (Mahesar et al., 2014). In fact, high quality oils are low in FFA which makes it more palatable to man (Aremu et al., 2015). Its low value makes it quality oil that can compete with other vegetable oils in the market.

#### 3.3.3 Saponification value

This ranges from 125.6-128.6 mg/NaOH/g as shown in Table 4. Saponification value measures the level of oxidation and deterioration of oils during storage and high value of it is desirable. Its high value is an indication that almond oil contains high proportion of lower fatty acids and hence edible (Aremu et al., 2015).

#### 3.3.4 Iodine value

Table 4 shows that iodine value of almond oil ranges from 60.6-69.4 (mg I<sub>2</sub>/g). Aremu et al. (2015) reported that oils with iodine value less than 100 g I<sub>2</sub>/100 g of oil are considered non-drying oils while oils with values of 130 above are good drying oils. Hence, almond oil produced within this range of process parameters is non-drying oil and has lower susceptibility to oxidative rancidity because of its low iodine value.

**Table 4 Physico-chemical properties of almond oil**

S/N	Parameters				Chemical properties					Physical properties				
	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	AV	FFA	SV	IV	PV	R.I	pH	FIP	FLP	V.I
1	85	6.14	14	7	1.920	0.960	126.1	64.10	2.760	1.4828	5.50	261	214	48.4
2	95	6.14	14	7	1.795	0.897	128.1	65.60	2.806	1.4861	5.52	262	213	47.6
3	85	6.72	14	7	2.356	1.178	127.4	65.00	2.808	1.4859	5.51	261	212	51.8
4	95	6.72	14	7	2.693	1.346	128.0	65.10	2.802	1.4860	5.50	262	210	46.6
5	85	6.14	22	7	2.693	1.346	127.9	65.20	2.801	1.4850	5.49	262	214	51.8
6	95	6.14	22	7	1.795	0.897	127.8	65.40	2.803	1.4860	5.51	261	212	46.9
7	85	6.72	22	7	1.800	0.900	123.1	63.90	2.700	1.4830	5.43	262	209	44.6
8	95	6.72	22	7	1.795	0.897	128.1	60.90	2.804	1.4857	5.51	261	214	47.8
9	85	6.14	14	9	1.967	0.954	128.0	64.80	2.803	1.4862	5.50	262	210	48.7
10	95	6.14	14	9	1.335	0.668	126.6	66.50	2.810	1.4856	5.49	261	208	46.9
11	85	6.72	14	9	1.571	0.785	125.6	67.20	2.800	1.4852	5.50	261	200	44.6
12	95	6.72	14	9	1.967	0.954	128.0	67.20	2.804	1.4861	5.50	261	212	48.9
13	85	6.14	22	9	1.967	0.954	127.8	66.20	2.801	1.4857	5.51	261	209	47.6
14	95	6.14	22	9	1.009	0.505	128.4	63.80	2.800	1.4860	5.50	261	208	48.3
15	85	6.72	22	9	2.580	1.290	127.6	69.40	2.806	1.4860	5.50	262	212	47.2
16	95	6.72	22	9	1.967	0.954	128.0	64.80	2.803	1.4862	5.50	262	210	48.7
17	80	6.43	18	8	1.680	0.840	122.08	65.80	2.810	1.4826	5.46	260	212	48.7
18	100	6.43	18	8	1.009	0.505	128.0	63.40	2.811	1.4i62	5.50	260	214	52.0
19	90	5.84	18	8	1.346	0.673	128.6	67.40	2.813	1.4863	5.52	261	215	51.2
20	90	7.01	18	8	1.967	0.954	128.	64.80	2.803	1.4862	550	262	210	48.7
21	90	6.43	10	8	1.571	0.785	128.2	65.70	2.808	1.4861	5.49	261	208	46.2
22	90	6.43	26	8	1.335	0.668	126.6	66.20	2.806	1.4858	5.50	260	212	52.0
23	90	6.43	18	6	1.683	0.842	128.4	66.20	2.806	1.4858	5.50	261	211	48.9
24	90	6.43	18	10	1.967	0.954	128.0	64.80	2.803	1.4862	5.50	262	210	48.7
25	90	6.43	18	8	1.967	0.954	128.0	64.80	2.803	1.4862	5.50	262	210	48.7
26	90	6.43	18	8	1.346	0.673	127.4	66.60	2.810	1.4861	5.49	260	210	48.2
27	90	6.43	18	8	1.790	0.897	128.1	66.80	2.812	1.4860	5.48	260	213	48.9
28	90	6.43	18	8	1.795	0.897	128.1	66.00	2.811	1.4861	551	262	213	50.6
29	90	6.43	18	8	2.580	1.290	127.4	66.40	2.803	1.4860	5.50	262	211	46.2
30	90	6.43	18	8	1.967	0.954	128.0	64.80	2.803	1.4862	5.50	262	210	48.7

### 3.3.5 Peroxide value

This is the most common indicator of lipid oxidation (Aremu et al., 2015). It ranges from 2.7-2.812 (Meq/g) as shown in Table 4. Oxidation of oils is the major cause of oil deterioration (Gunstone, 2002) and high peroxide values indicates high levels of oxidative rancidity. According to Aremu et al. (2015), the permitted maximum peroxide value for standard quality oil is 10 milliequivalents of active oxygen/kg oil (CODEX-STAN, 1999). Hence, the almond oil produced is a good quality oil based on its low peroxide value which is within the range of standard acceptable for edible oils.

### 3.3.6 Refractive index

This is used in quality control for establishing oil purity, observing the progress of reaction rapidly and for source oil identification (Gunstone, 2002). The range of values (1.4826-1.4863) for almond oil produced is within

the acceptable range given in codex standards for fats and oil (CODEX-STAN, 1999).

### 3.3.7 pH values

From Table 4, the pH values of almond oil produced ranges from 5.43-5.52 which indicates that the oil is acidic in nature probably because of its free fatty acid content.

### 3.3.8 Fire point and flash point

These are associated with the FFA content of oils in that the temperature values obtained as fire point and flashpoint are lower for oils with high FFA content or with short chain free fatty acids. Fire point is the temperature at which volatiles are produced in quantity that will support flame while flash point is the temperature at volatiles are produced in quantity that can ignite but do not support flame (Gunstone, 2002). Hence, the fire point and flash point ranges from 260-262°C and

200-215°C, respectively as shown in Table 4. And in relation to the FFA content which ranges from 0.505-1.346 which is low, hence giving reason to their high values. This shows that this is a desirable quality since quality oils are expected to have low FFA content.

### 3.3.9 Viscosity

Low viscosity indicates that the oil is light and maybe highly unsaturated. High viscosity values sometimes might be as a result of suspended particles in crude oil. The more viscous a vegetable oil is, the better it is used as a lubricant. Table 4 shows that the almond oil produced within the chosen range of process parameters had a

viscosity value ranging from 44.6-52 c.p which is low when compared to that of shea butter that ranges from 80-100 c.p (Olaniyan and Oje, 2007).

### 3.3.10 Colour

Figure 8 shows the colour variation of the almond oil produced within the selected range of process parameters. The numbering on the oil sample bottle represents the run number as shown in Table 2. This indicates that the dominant colour of almond oil produced is light yellow with variation in intensity which is golden at process parameters with high temperature, heating time and low moisture content.

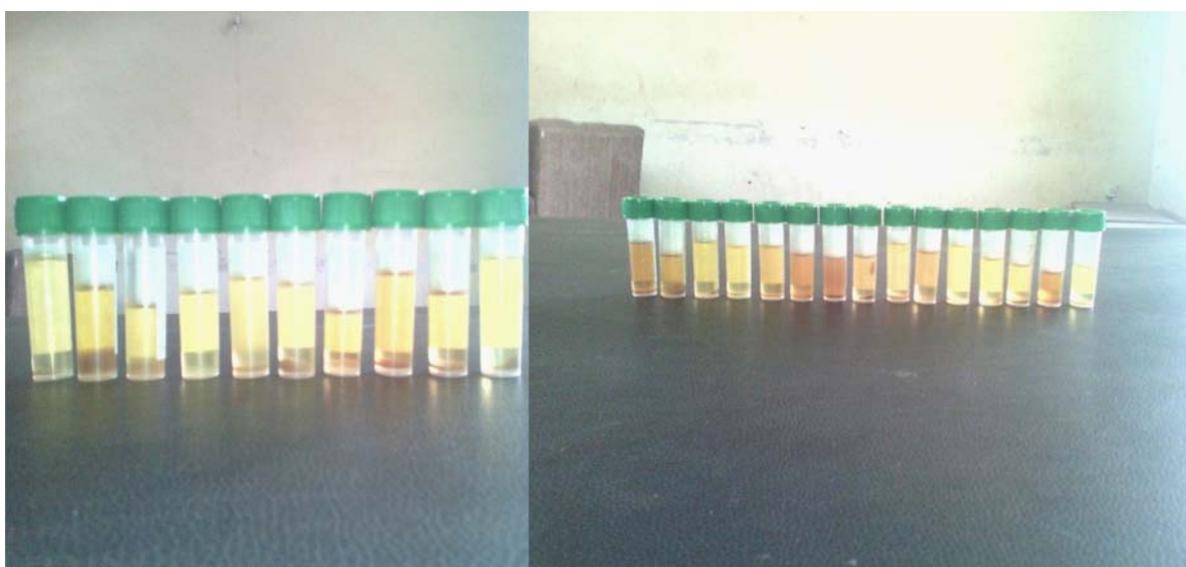


Figure 8 Colour variation of almond oil samples produced

## 4 Conclusion

This study on the effect of process parameters on expression efficiency of mechanically expressed almond oil using CCD revealed that all the four variables had significant effect on expression efficiency. Moisture content had the most significant effect while heating time had the least effect on expression efficiency. Optimum expression efficiency of 76.35% was obtained at temperature, pressure, heating time and moisture content of 93.34°C, 6.44 MPa, 17.16 min and 8.71% wb respectively. This implies that mechanical expression method used performed satisfactorily well even though there is need to further develop it through improving the expression and energy efficiency and by increasing their handling capacities. This approach can be of great help in recovery most of the oil from the kernel. Finally, the

physio-chemical properties of the oil conform to the CODEX standard for edible oil.

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