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*Full Length Research Paper*

# Influence of Variety and Pre-treatment on Oil Properties of Mechanically Expressed Castor Oil

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**Oil was mechanically expressed from four varieties of pre-treated castor seeds, namely: white big size (WBS), black big size (BBS), grey medium size (GMS) and grey small size (GSS) using hydraulic press. The expressed oils were analyzed to investigate the effects of pre-treatment (nature of seed and heating method) on some of these properties (acid value, saponification value, iodine value, specific gravity, viscosity, refractive index, pH value and peroxide value) of these varieties. Mathematical models for acid and saponification values of castor oil were developed by factorial analysis. The studied factors were seed variety (WBS, BBS, GMS and GSS), nature of seed (dehulled and undehulled seeds) and heating method (raw, boiled and roasted seeds). It was revealed that acid value and saponification value were significantly affected by seed variety and heating method at 5% level of significance, while iodine value, specific gravity, viscosity, refractive index, pH value and peroxide value were not statistically affected by seed variety, heating method and nature of seed. The model predicted that the maximum and minimum acid values were 3.88% and 0.66% from WBS (roasted and undehulled) and GMS (raw and dehulled) respectively. While the maximum and minimum saponification values were 195.19% and 166.53% from BBS (roasted and undehulled) and GMS (raw and dehulled) respectively.**

**Keywords:** Castor seed, castor oil, oil expression, oil properties, seed variety, model equation

## INTRODUCTION

Castor plant, (*Ricinus communist L.)* is a member of the Euphorbiaceae, which contains a vast number of plants mostly native to the tropics (Akpan, *et al. 2006* ). In Nigeria, castor is obtained in every part of the country. Its seed contains 40 to 60 % oil (Olaoye, 2000). The seed is referred to differently depending on the locality where it is found. The Yorubas call it 'Lara', the Hausas refer to it as 'Zurma', and the Kanuris call it 'Kwolakwola', while the Igbos refers to it as Ogilisi (Oluwole, 2010). The oil extracted from the seed is traditionally used as medicinal ointment, illuminant, and as raw material in the soap making industry. At present, the potential of castor oil is not fully explored in Nigeria. Plate 1 shows the seeds of four common varieties of the crop that have been identified. These have been named as White Big Size (WBS), Black Big Size (BBS), Grey Medium Size (GMS) and Grey Small Size (GSS) (Oluwole, 2010). Castor seed oil is a colorless to very pale yellow liquid with mild or no


**Plate 1.** Common Castor seeds: A -WBS; B -BBS;
C -GMS; D –GSS
((WBS)-White Big Size, (BBS)-Black Big Size,
(GMS)- Grey Medium Size and (GSS)-Grey Small Size)

**Plate 2.** Hydraulic Press used for the oil Expression

odor or taste (Akpan, *et al. 2006*). The oil is essentially a pure triglyceride and contains almost 90% of glyceryltrianoleate (Marter, 1981). Castor oil is an amber viscous liquid and is sometimes known as ricinus oil (Marter, 1981). The oil itself contains a number of fatty acids such as oleic acid, liniteic acid, stearic acid and palmitic acid. Among the vegetable oil however, castor oil is distinguished by its high content of ricinoleic acid than any other vegetable oil (Chakrabarti and Rafiq 2008). Castor oil is unique as it is the only source of an 18-carbon hydroxylated acid with one double bond (Chakrabarti and Rafiq 2008). The product uniformity and consistency of castor oil are significantly high for a naturally occurring material. It has unsaturated bond, high molecular weight, low melting point and very low solidification point which make it industrially useful. The pure cold drawn (expressed) castor oil is used as a purgative (Olaniyan, 2010), it also have applications in the manufacturing of soaps, lubricants, hydraulic and brake fluids, paints, dyes, coating, inks, cold resistant, plastics, varnishes, lacquers, oil clothes, linoleum grease, waxes and polishes, nylon, pharmaceuticals and perfumes and also as a raw material in the manufacturing of various chemicals (Oluwole, 2010).

Three major means of recovering oil from oil-bearing biological materials was reported by Olaniyan (2010): wet extraction; solvent extraction and mechanical expression. The wet extraction process is known as hot water or steam extraction method, which is the oldest method of extraction used traditionally by women in rural communities. Alonge and Olaniyan (2003) and Addaquay (2004) used this method for shea butter extraction, Alonge *et al.* (2003) for groundnut oil extraction, Alonge and Olaniyan (2006) for thevetia oil extraction. The same method was used by Oluwole *et al.* (2012) for castor seed oil extraction. The result showed percent of oil expression of 19.42%, which is below the range of the percentage oil content (30 – 55%) of castor seed found in literature (Olaniyan*,* 2010).

Akpan *et al.* (2006) carried out an investigation on extraction, characterization and modification of castor seed oil using solvent extraction method. Result showed percentage oil extraction of 33.2%. In another development, Shridhar *et al.* (2010) carried out an optimization and characterization of castor seed oil using solvent extraction method. Result showed percentage of oil extraction of 48.75%. Also Abitogun *et al.* (2009) extracted and characterized castor seed oil using solvent

Table 1: Properties of oil from pre-treated castor seeds

| Std | Seed Variety | Nature of Seed | Heating Method | Acid Value | Saponification Value | Iodine Value | Specific Gravity | Viscosity | Refractive Index | pH Value | Peroxide Value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | WBS | Dehulled | Raw | 2.00 | 183.43 | 82.33 | 0.965 | 1465 | 1.4773 | 4.01 | 8.6 |
| 2 | WBS | Undehulled | Raw | 2.61 | 180.62 | 86.65 | 0.965 | 1509 | 1.4772 | 4.02 | 9.7 |
| 3 | WBS | Dehulled | Boiled | 2.97 | 185.16 | 87.07 | 0.994 | 1680 | 1.4773 | 4.03 | 10.6 |
| 4 | WBS | Undehulled | Boiled | 3.20 | 186.55 | 89.67 | 0.983 | 1389 | 1.4766 | 4.06 | 15.6 |
| 5 | WBS | Dehulled | Roasted | 3.65 | 188.93 | 88.21 | 0.989 | 1185 | 1.4774 | 4.04 | 5.4 |
| 6 | WBS | Undehulled | Roasted | 3.93 | 190.92 | 90.09 | 0.957 | 1014 | 1.4771 | 4.08 | 8.4 |
| 7 | BBS | Dehulled | Raw | 1.40 | 180.11 | 84.76 | 0.956 | 1430 | 1.4771 | 4.01 | 9.6 |
| 8 | BBS | Undehulled | Raw | 1.52 | 181.43 | 86.22 | 0.962 | 1155 | 1.4765 | 4.03 | 11.2 |
| 9 | BBS | Dehulled | Boiled | 1.96 | 189.34 | 85.65 | 0.978 | 1617 | 1.4775 | 4.05 | 6.8 |
| 10 | BBS | Undehulled | Boiled | 2.36 | 190.74 | 98.98 | 0.984 | 1323 | 1.4774 | 4.04 | 8.0 |
| 11 | BBS | Dehulled | Roasted | 3.03 | 196.35 | 90.09 | 0.827 | 1230 | 1.4773 | 4.03 | 11.0 |
| 12 | BBS | Undehulled | Roasted | 3.14 | 194.94 | 97.71 | 0.843 | 1572 | 1.4772 | 4.02 | 10.6 |
| 13 | GMS | Dehulled | Raw | 1.01 | 165.32 | 85.78 | 0.965 | 1222 | 1.4772 | 4.04 | 4.3 |
| 14 | GMS | Undehulled | Raw | 1.06 | 168.54 | 87.22 | 0.876 | 1232 | 1.4765 | 4.06 | 8.6 |
| 15 | GMS | Dehulled | Boiled | 1.21 | 170.32 | 82.01 | 0.956 | 1300 | 1.4768 | 4.03 | 4.1 |
| 16 | GMS | Undehulled | Boiled | 1.57 | 173.91 | 81.21 | 0.954 | 1320 | 1.4768 | 4.08 | 4.0 |
| 17 | GMS | Dehulled | Roasted | 2.21 | 178.76 | 84.06 | 0.945 | 1260 | 1.4772 | 4.01 | 4.3 |
| 18 | GMS | Undehulled | Roasted | 1.63 | 180.92 | 81.85 | 0.880 | 1365 | 1.4773 | 4.03 | 4.0 |
| 19 | GSS | Dehulled | Raw | 1.40 | 178.69 | 85.23 | 0.905 | 1325 | 1.4774 | 4.02 | 6.2 |
| 20 | GSS | Undehulled | Raw | 1.52 | 180.15 | 83.78 | 0.945 | 1360 | 1.4767 | 4.03 | 5.2 |
| 21 | GSS | Dehulled | Boiled | 1.96 | 181.09 | 84.65 | 0.955 | 1320 | 1.4775 | 4.04 | 5.7 |
| 22 | GSS | Undehulled | Boiled | 2.52 | 185.13 | 85.65 | 0.905 | 1590 | 1.4774 | 4.04 | 6.4 |
| 23 | GSS | Dehulled | Roasted | 3.03 | 183.33 | 91.07 | 0.925 | 1455 | 1.4773 | 4.02 | 10.1 |
| 24 | GSS | Undehulled | Roasted | 3.14 | 190.74 | 97.71 | 0.955 | 1260 | 1.4773 | 4.03 | 11.2 |

extraction method. Result showed that 48% oil was extracted. It was reported by Akpan *et al.* (2006) that the best available method for castor oil extraction at present is by the use of hydraulic press.

According to Olaniyan (2010), oilseed pre-treatment prior to oil extraction/expression normally affects oil yield and quality. Increase in castor seed heating temperature increases oil yield / oil recovery and oil properties such as Free Fatty Acid (FFA), total acid value, iodine value, saponification value and peroxide value (Olaniyan, 2010). Tuned-Akintunde *et al.* (2001) investigated the effects of moisture content, heating temperature, heating time, applied pressure and pressing time on soybean oil yield using mechanical press. Result showed that oil yield increased as moisture content was varied from 7.3 –10.2%, pressure from 28 – 41 MPa, heating temperature from 70 – 80 $^{O}$C and heating time from 15 – 30 minutes. Fashina and Ajibola (1989) investigated the effects of moisture content, heating temperature, heating time, applied pressure and pressing time on the yield of oil expressed from conophor nuts. Result showed that the oil yield at any pressure was dependent on the moisture content of the sample. High oil yield was reported for samples within moisture content range of 8 and 10% after heating. The maximum oil yield of 39.6% (66% extraction efficiency) was obtained when milled conophor nut conditioned to 11% moisture content was heated at 65 $^{O}$C for 28 minutes and expressed at a pressure of 25 MPa.

Olaniyan (2010) investigated effects of extraction conditions on the yield and quality of oil from castor seed. Result showed maximum oil yield of 41.67% (75.76% oil recovery) at heating temperature of 90 $^{O}$C, pressure of 135 kPa and pressing time of 12 minutes using crushed seed. The percentages of oil extracted or expressed

**Table 2.** ANOVA of Acid Value

| Source | Sum of Squares | df | Mean Square | F Value | p-value Prob > F | |
|---|---|---|---|---|---|---|
| Model | 15.94 | 6 | 2.66 | 49.81 | < 0.0001 | **significant** |
| A-Seed variety | 7.79 | 3 | 2.60 | 48.73 | < 0.0001 | |
| B-Nature of seed | 0.23 | 1 | 0.23 | 4.39 | 0.0515 | |
| C-Heating method | 7.91 | 2 | 3.95 | 74.16 | < 0.0001 | |
| Residual | 0.91 | 17 | 0.05 | | | |
| Cor Total | 16.84 | 23 | | | | |

$R^2$ = 0.9462

**Table 3.** ANOVA of Saponification Value

| Source | Sum of Squares | df | Mean Square | F Value | p-value Prob > F | |
|---|---|---|---|---|---|---|
| Model | 1350.10 | 6 | 225.02 | 46.03 | < 0.0001 | significant |
| A-Seed variety | 857.82 | 3 | 285.94 | 58.50 | < 0.0001 | |
| B-Nature of seed | 23.52 | 1 | 23.52 | 4.81 | 0.0425 | |
| C-Heating method | 468.76 | 2 | 234.38 | 47.95 | < 0.0001 | |
| Residual | 83.10 | 17 | 4.89 | | | |
| Cor Total | 1433.20 | 23 | | | | |

$R^2$ = 0.9420

from castor seed by these researchers using solvent extraction method or mechanical expression method fall within the range of the percentage oil content (30 – 55%) of castor seed found in literature (Akpan *et al.,* 2006; Olaniyan, 2010; and Shridhar *et al.,* 2010), depending on the variety.

Oluwole *et al.,* (2014) investigated influence of variety on oil yield and oil recovery of castor seed. Their results showed oil yield/oil recovery of 28.69/52.16, 21.23/38.60, 34.87/63.40 and 30.65/55.72% for undehulled WBS, BBS, GMS and GSS respectively; oil yield/oil recovery of 35.43/ 64.42, 27.98/50.87, 41.62/ 75.67 and 37.39/ 67.99% for dehulled WBS, BBS, GMS and GSS respectively. Though, something close to 100% oil recovery (55% oil yield) would have been expected, but the mode of extraction and seed variety are very important parameters affecting the oil yield as reported (Akpan *et al.,* 2006). This study aims at investigating the varietal and pre-treatment effects on quality of mechanically expressed castor seed oil. Information obtained from this study would elucidate the problems of castor oil expression and enable the development of processing method that will yield high-quality oil for micro, small and medium scale castor oil processors.

## MATERIALS AND METHODS

### Materials Sourcing

Bulk quantities of the four varieties of castor seeds namely; white big size (WBS), black big size (BBS), grey medium size (GMS) and grey small size (GSS) were collected from different localities in Borno and Yobe States of Nigeria.

### Moisture Content Determination

Prior to oil extraction, the moisture contents of the seeds were determined using the method reported by ASAE (1983), Aviara *et al.* (2005), Oluwole *et al.* (2007). This method involves oven drying of samples at 130$^{O}$C for 6 hours.

### Oil Expression

The four varieties of castor seeds were prepared for the oil expression by drying the seeds to a moisture content

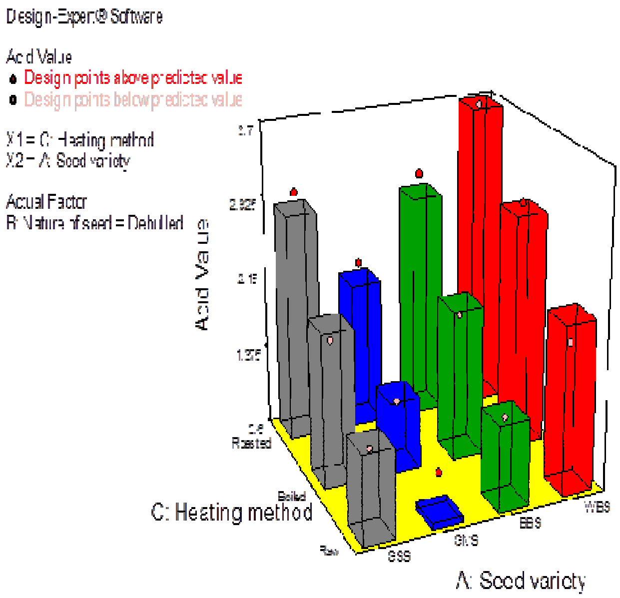


Figure 1: Effects of seed variety and heating method on acid value of oil from dehulled castor seeds

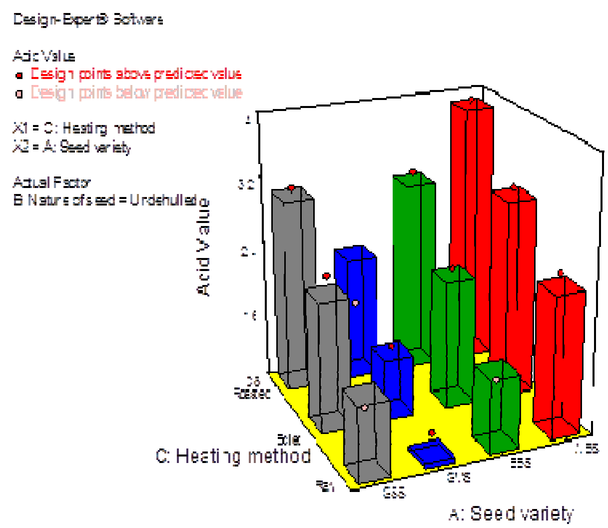


Figure 2: Effects of seed variety and heating method on acid value of oil from undehulled castor seeds

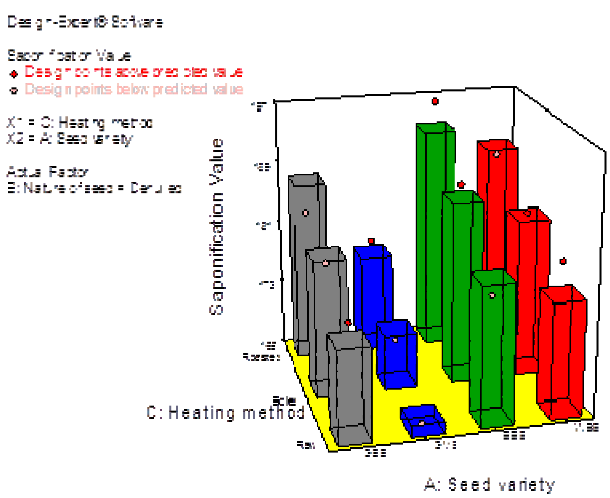


Figure 3: Effects of seed variety and heating method on saponification value of oil from dehulled castor seeds

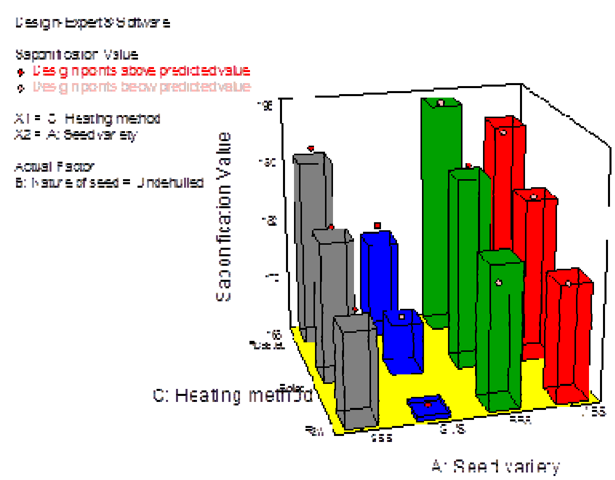


Figure 4: Effects of seed variety and heating method on saponification value of oil from undehulled castor seeds

of 5 to 6% (db), each variety was divided into three (3) portions (Raw – sample A, Boiled - sample B and Roasted- sample C). Each of these portions was further divided into two (2) to have dehulled and undehulled

**Table 4.** Regression coefficient of the oil acid value

| Term | Coefficient Estimate | df | Standard Error | 95% CI Low | 95% CI High | VIF |
|---|---|---|---|---|---|---|
| Intercept | 2.25 | 1 | 0.05 | 2.15 | 2.36 | |
| $A_1$ | 0.81 | 1 | 0.09 | 0.63 | 0.99 | |
| $A_2$ | 0.02 | 1 | 0.09 | -0.17 | 0.20 | |
| $A_3$ | -0.80 | 1 | 0.09 | -0.99 | -0.62 | |
| B- nature of seed | 0.08 | 1 | 0.05 | -0.02 | 0.19 | 1.00 |
| $C_1$ | -0.69 | 1 | 0.07 | -0.84 | -0.54 | |
| $C_2$ | -0.03 | 1 | 0.07 | -0.18 | 0.12 | |

$R^2$ = 0.9462

**Table 5.** Regression coefficient of the oil saponification value

| Term | Coefficient Estimate | df | Standard Error | 95% CI Low | 95% CI High | VIF |
|---|---|---|---|---|---|---|
| Intercept | 182.73 | 1 | 0.45 | 181.77 | 183.68 | |
| $A_1$ | 3.21 | 1 | 0.78 | 1.56 | 4.86 | |
| $A_2$ | 6.09 | 1 | 0.78 | 4.44 | 7.74 | |
| $A_3$ | -9.76 | 1 | 0.78 | -11.41 | -8.11 | |
| B-nature of seed | 0.99 | 1 | 0.45 | 0.04 | 1.94 | 1.00 |
| $C_1$ | -5.44 | 1 | 0.64 | -6.79 | -4.09 | |
| $C_2$ | 0.05 | 1 | 0.64 | -1.29 | 1.40 | |

$R^2$ = 0.9420

samples. The raw seeds, sample A were kept as control samples while the other two samples (B and C) were prepared for the experiments.

The process conditions include two heating methods (boiling and roasting with raw as control sample), three heating temperatures of 30 $^{O}$C, 60 $^{O}$C and 90 $^{O}$C and three heating time durations of 5 min, 10 min and 15 min. at constant pressing pressure of 135 N/m$^2$, and pressing time of 12 min was adopted. These ranges of heating temperature and heating time were chosen based on literature review and preliminary laboratory experiments (Olaniyan, 2010). 3 kg of each sample was weighed, roasted at 30, 60 and 90 $^{O}$C for 5, 10 and 15 min, and boiled at 30, 60 and 90 $^{O}$C for 5, 10 and 15 min. The boiled samples were sun dried in open air for 24 hrs. Oil expression was accomplished using 100g of each sample, which was expressed for 12 min, using a hydraulic press shown in Plate 2 at pressure of 135 N/m$^2$. The same procedure was repeated for dehulled seed and undehulled seed samples with three replicates making a total of 456 experimental trials that were carried out and the average values were recorded.

Oil yield ($\zeta_{oil}$) was calculated as;

$\zeta_{oil} = M_{oil}/M_{seed}$ x 100 % (1) Oil recovery was calculated as;

$\zeta_{oil\ rec} = M_{oil}/XM_{seed}$ x 100 % (2)

Where $M_{oil}$ = mass of oil expressed, kg

$M_{seed}$ = mass of oil seed, kg

X = oil content of oilseed (0.55 or 55 % from Olaniyan, 2010)

The applied expression force was obtained from the gauge of the hydraulic press and the expression pressure was calculated by dividing the applied force by the cross-sectional area of the press cage cylinder. Samples of oil expressed were subjected to physio-chemical analysis to determine the quality using the AOAC (2002) method. Data obtained from the experiments for measured output were statistically analyzed for analysis of variance (ANOVA) using Design Expert 7.0 Software.

### Characterization of the Expressed Oil

The expressed oils from the four castor seeds varieties with different pre-treatments were characterized to determine some of their properties (acid value (AV), Iodine Value (IV), Saponification Values, Peroxide Value, Refractive Index, relative density (Specific gravity),

**Table 6.** Factorial design of the significant oil properties using coded factors

| S/No. | Seed Variety | | Nature of Seed | | Heating Method | | Acid Value | | Saponification Value | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Actual | Coded | Actual | Coded | Actual | Coded | Actual | Predicted | Actual | Predicted |
| 1 | WBS | {1 0 0} | Dehulled | {-1} | Raw | {1 0} | 2.00 | 2.28 | 183.43 | 179.51 |
| 2 | BBS | {0 1 0} | Dehulled | {-1} | Raw | {1 0} | 1.40 | 1.45 | 180.11 | 182.39 |
| 3 | GMS | {0 0 1} | Dehulled | {-1} | Raw | {1 0} | 1.01 | 0.66 | 165.32 | 166.53 |
| 4 | GSS | {-1-1-1} | Dehulled | {-1} | Raw | {1 0} | 1.40 | 1.48 | 178.69 | 176.76 |
| 5 | WBS | {1 0 0} | Undehulled | {1} | Raw | {1 0} | 2.61 | 2.47 | 180.62 | 181.49 |
| 6 | BBS | {0 1 0} | Undehulled | {1} | Raw | {1 0} | 1.52 | 1.65 | 181.43 | 184.37 |
| 7 | GMS | {0 0 1} | Undehulled | {1} | Raw | {1 0} | 1.06 | 0.86 | 168.54 | 168.51 |
| 8 | GSS | {-1-1-1} | Undehulled | {1} | Raw | {1 0} | 1.52 | 1.67 | 180.15 | 178.74 |
| 9 | WBS | {1 0 0} | Dehulled | {-1} | Boiled | {0 1} | 2.97 | 2.93 | 185.16 | 185.00 |
| 10 | BBS | {0 1 0} | Dehulled | {-1} | Boiled | {0 1} | 1.96 | 2.10 | 189.34 | 187.88 |
| 11 | GMS | {0 0 1} | Dehulled | {-1} | Boiled | {0 1} | 1.21 | 1.32 | 170.32 | 172.03 |
| 12 | GSS | {-1-1-1} | Dehulled | {-1} | Boiled | {0 1} | 1.96 | 2.13 | 181.09 | 182.25 |
| 13 | WBS | {1 0 0} | Undehulled | {1} | Boiled | {0 1} | 3.20 | 3.13 | 186.55 | 186.98 |
| 14 | BBS | {0 1 0} | Undehulled | {1} | Boiled | {0 1} | 2.36 | 2.30 | 190.74 | 189.86 |
| 15 | GMS | {0 0 1} | Undehulled | {1} | Boiled | {0 1} | 1.57 | 1.51 | 173.91 | 174.01 |
| 16 | GSS | {-1-1-1} | Undehulled | {1} | Boiled | {0 1} | 2.52 | 2.33 | 185.13 | 184.23 |
| 17 | WBS | {1 0 0} | Dehulled | {-1} | Roasted | {-1 -1} | 3.65 | 3.68 | 188.93 | 190.33 |
| 18 | BBS | {0 1 0} | Dehulled | {-1} | Roasted | {-1 -1} | 3.03 | 2.86 | 196.35 | 193.21 |
| 19 | GMS | {0 0 1} | Dehulled | {-1} | Roasted | {-1 -1} | 2.21 | 2.07 | 178.76 | 177.36 |
| 20 | GSS | {-1-1-1} | Dehulled | {-1} | Roasted | {-1 -1} | 3.03 | 2.88 | 183.33 | 187.58 |
| 21 | WBS | {1 0 0} | Undehulled | {1} | Roasted | {-1 -1} | 3.93 | 3.88 | 190.92 | 192.31 |
| 22 | BBS | {0 1 0} | Undehulled | {1} | Roasted | {-1 -1} | 3.14 | 3.05 | 194.94 | 195.19 |
| 23 | GMS | {0 0 1} | Undehulled | {1} | Roasted | {-1 -1} | 1.63 | 2.27 | 180.92 | 179.34 |
| 24 | GSS | {-1-1-1} | Undehulled | {1} | Roasted | {-1 -1} | 3.14 | 3.08 | 190.74 | 189.56 |

viscosity and pH value) following the procedures described by Akpan *et al.* (2006), Abitogun *et al.* (2009) and Shridhar *et al.* (2010).

## RESULTS AND DISCUSSION

Using the formulae as indicated in the experimental procedures, properties of oil from pre-treated

### Effects of seed pre-treatment on oil properties

Tables 2 and 3 show the ANOVA of acid value and saponification value of the expressed oil respectively. It can be seen from these tables that seed variety and heating method significantly affected the acid and saponification values of the expressed oil. These results agree with the findings of Adeeko and Ajibola (1989), Olaniyan and Oje (2007) and Olaniyan (2010). Figures 1 and 2; and Figures 3 and 4 showed the effects of seeds variety and heating method on the oil acid and saponification values for dehulled and undehulled seeds respectively. It is evident from these Figures that the roasted seeds have the highest acid value and saponification value followed by the boiled seeds and the least is observed from the raw seeds. It is obvious that the WBS have the highest percentage of acid value followed by the BBS, then the GSS and the least value is observed from the GMS; while the BBS have the highest saponification value followed by the WBS then the GSS and the least is from the GMS.

Tables 4 and 5 present the regression coefficient of acid value and saponification value models of expressed castor oil. The negative coefficient terms in equations 3- 28 obtained from Tables 4 and 5 indicated that the factors have negative influence, while the positive terms
in the equations indicated that the factors have positive influence on the acid and saponification values of the oil. In order to validate the model developed, experimental data generated in Table 6 (in terms of coded values)

were substituted in equations 3 and 16 and the predicted acid and saponification values were obtained as shown in Table 6. The model predicted that the maximum acid value was 3.88% from roasted and undehulled WBS and the minimum acid value was 0.66% from raw and dehulled GMS. While the maximum saponification value was 195.19% from roasted and undehulled BBS and the minimum saponification value was 166.53% from raw and dehulled GMS. It is obvious from this Table that the comparison of experimental (actual) values with the predicted values is in close proximity.

$$Acid\ Value = 2.25 + 0.81A_1 + 0.015A_2 - 0.80A_3 + 0.082B - 0.69C_1 - 0.029C_2 \quad 3$$

where A stand for the coded value of seed variety (for WBS, values of $\{A_1, A_2, A_3\} = \{1, 0, 0\}$; for BBS = {0, 1, 0}; for GMS ={0, 0, 1} and for GSS ={-1, -1, -1} and B stand for the coded value of nature of seed) (for Dehulled seed, value of {B} = {1}; for Undehulled seed, {B} = {-1} and C stands for the coded value of heating method (for Raw seed, value of $\{C_1, C_2\}$ ={1, 0} for Boiled seed, value of $\{C_1, C_2\}$ ={0, 1}; for Roasted seed, $\{C_1, C_2\}$ ={-1, -1}.

In order to validate the developed model, the coded values above were substituted in equation 3, from where equetions 4 – 15 were generated for each of the seed sample.

$$Acid\ Value_{WBS\ Raw} = 2.25 + 0.81A_1 + 0.082B - 0.69C_1 \quad 4$$

$$Acid\ Value_{WBS\ Boiled} = 2.25 + 0.81A_1 + 0.082B - 0.029C_2 \quad 5$$

$$Acid\ Value_{WBS\ Roasted} = 2.25 + 0.81A_1 + 0.082B + 0.72C_3 \quad 6$$

$$Acid\ Value_{BBS\ Raw} = 2.25 + 0.015A_2 + 0.082B - 0.69C_1 \quad 7$$

$$Acid\ Value_{BBS\ Boiled} = 2.25 + 0.015A_2 + 0.082B - 0.029C \quad 8$$

$$Acid\ Value_{BBS\ Roasted} = 2.25 + 0.015A_2 + 0.082B + 0.72C_3 \quad 9$$

$$Acid\ Value_{GMS\ Raw} = 2.25 - 0.80A_3 + 0.082B - 0.69C_1 \quad 10$$

$$Acid\ Value_{GMS\ Boiled} = 2.25 - 0.80A_3 + 0.082B - 0.029C_2 \quad 11$$

$$Acid\ Value_{GMS\ Roasted} = 2.25 - 0.80A_3 + + 0.082B + 0.72C_3 \quad 12$$

$$Acid\ Value_{GSS\ Raw} = 2.25 - 0.03A_4 + 0.082B - 0.69C_1 \quad 13$$

$$Acid\ Value_{GSS\ Boiled} = 2.25 - 0.03A_4 + 0.082B - 0.029C_2 \quad 14$$

$$Acid\ Value_{GSS\ Roasted} = 2.25 - 0.03A_4 + 0.082B + 0.72C_3 \quad 15$$

$$Saponification\ Value = 182.73 + 3.21A_1 + 6.09A_2 - 9.76A_3 + 0.99B - 5.44C_1 + 0.054C_2 \quad 16$$

where A stand for the coded value of seed variety; for WBS, values of $\{A_1, A_2, A_3\} = \{1, 0, 0\}$; for BBS = {0, 1, 0}; for GMS ={0, 0, 1} and for GSS ={-1, -1, -1} and B stand for the coded value of nature of seed; for Dehulled seed, value of {B} = {1}; for Undehulled seed, {B} = {-1} and C stands for the coded value of heating method; for Raw seed, value of $\{C_1, C_2\}$ ={1, 0} for Boiled seed, value of $\{C_1, C_2\}$ ={0, 1}; for Roasted seed, $\{C_1, C_2\}$ ={-1, -1}.

In order to validate the developed model, the coded values above were substituted in equation 16, from where equetions 17 – 28 were generated for each of the seed sample.

$$Saponification\ Value_{WBS\ Raw} = 182.73 + 3.21A_1 + 0.99B - 5.44C_1 \quad 17$$

$$Saponification\ Value_{WBS\ Boiled} = 182.73 + 3.21A_1 + 0.99B + 0.054C_2 \quad 18$$

$$Saponification\ Value_{WBS\ Roasted} = 182.73 + 3.21A_1 + 0.99B + 5.39C_3 \quad 19$$

$$Saponification\ Value_{BBS\ Raw} = 182.73 + 6.09A_2 + 0.99B - 5.44C_1 \quad 20$$

$$Saponification\ Value_{BBS\ Boiled} = 182.73 + 6.09A_2 + 0.99B + 0.054C_2 \quad 21$$

$$Saponification\ Value_{BBS\ Roasted} = 182.73 + 6.09A_2 + 0.99B + 5.39C_3 \quad 22$$

$$Saponification\ Value_{GMS\ Raw} = 182.73 - 9.76A_3 + 0.99B - 5.44C_1 \quad 23$$

$$Saponification\ Value_{GMS\ Boiled} = 182.73 - 9.76A_3 + 0.99B + 0.054C_2 \quad 24$$

$$Saponification\ Value_{GMS\ Roasted} = 182.73 - 9.76A_3 + 0.99B + 5.39C_3 \quad 25$$

$$Saponification\ Value_{GSS\ Raw} = 182.73 + 0.46A_4 + 0.99B - 5.44C_1 \quad 26$$

$$Saponification\ Value_{GSS\ Boiled} = 182.73 + 0.46A_4 + 0.99B + 0.054C_2 \quad 27$$

$$Saponification\ Value_{GSS\ Roasted} = 182.73 + 0.46A_4 + 0.99B + 5.39C_3 \quad 28$$

## CONCLUSION

In this study, effects of seed variety, nature of seed and seed heating method on some properties of mechanically expressed castor seed oil were investigated. It was revealed that acid value and saponification value were significantly affected by seed variety and heating method while iodine value, specific gravity, viscosity, refractive index, pH value and peroxide value were not significantly affected by these factors. Castor oil has a lot of agro-industrial potentials, it is, therefore, necessary to select the most promising castor seed variety and seed pre-treatment in order to obtain high quality castor oil.

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