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Comparative Study on Extraction and Characterization of Castor Seed and Oil from Three Different State Capitals in Nigeria

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Abstract: Castor oil has versatile applications in various industrial sectors. It has been noted that castor oil differs depending on the geographical location in which the plant is grown. The aim of this study was to investigate the comparative studies of proximate, elemental and physicochemical characteristics of castor seed and oil collected from three different states (Ogbomoso in Oyo, Osogbo in Osun and Akure in Ondo States) of Western Nigeria. Castor seeds were obtained from three different States in South Western Nigeria. The seeds were sun-dried, ground and subjected to mechanical pressing using laboratory hydraulic press to obtain oil. The seeds from each States were separately analysed for proximate and minerals using standard analytical procedures. The extracted oil obtained from the castor seeds from each state was also analysed for physicochemical properties. The proximate analysis showed: % fat (67.41±0.01- 67.22±0.02), % ash (3.17±0.0-3.08±0.02), % protein (15.23±0.04-15.13±0.04). There is no significant difference in proximate parameters except for % fat and % ash contents at $p<0.05$ level. Physicochemical analyses revealed: % free fatty acid (FFA) 3.86±0.01-3.74±0.05, % specific gravity (SG) 0.62±0.03-0.61±0.01 and saponification value (SV) 124.00±0.00-120.00±0.00 mgKOH/g. The % oil yield ranged between 40.10±0.02-37.50±0.05. Sample from Ogbomoso gave the highest % yield. There is significant difference in the mineral (Na, K, Ca and Fe) concentrations from the three locations at $p<0.05$ level. The highest concentration of Na, K, Ca and Fe were from Ogbomoso (A). Castor seed analysed from the three states were free from heavy metals (Cd, Ni, Co and As).

Keywords: Castor Oil, Elemental Analysis, Physicochemical, Free Fatty Acid, Ondo State, Extraction, Heavy Metals

1. Introduction

Castor oil plant, *Ricinus communis L.* is a species of flowering plant in the spurge family, *Euphorbiaceae*. It is the sole species in the monotypic genus, *Ricinus*, and sub tribe, *Ricininae*. The name *Ricinus* is a Latin word for tick. The plant is named because its seed has markings and a dump at the end that resembles certain tick [1]. The plant is generally fast growing, but the castor beans are coldly hardy- they need a long frost-free season to mature. This is why the castor oil plant thrives in the Southeastern Mediterranean Basin, Eastern Africa, India, and other dry tropical regions of the world [2].

Castor seed is the source of castor oil, which has a wide variety of uses. The seeds contain between 40% and 60% oil that is rich in triglycerides, mainly ricinolein. The seed also contain ricin, a water soluble toxin, which is usually present in lower concentrations. Castor oil is normally obtained by solvents extraction or mechanical pressing of dried castor seeds. The high content of ricinoleic acid with its three functional groups of hydroxyl, carboxylate and carbon - carbon double bond (alkenes) is the main reason why castor oil has versatile application possibilities in chemical industry. It has been noted that castor oil differs depending on the geographical location in which the plant is grown and the agricultural modifications which have been made during growth [2, 3].

According to Kularni and Sawant [4], castor bean contains

35.55% oil by weight for high yield breed types and has one of the highest viscosities among vegetable oils, with a molecular weight of 298. It is one of the few naturally occurring triglycerides that approach being a pure compound, since the fatty acid portion is nearly nine-tenths ricinoleic [5]. Relative to other vegetable oils, castor oil has different physical and chemical properties which vary with the method of extraction (solvent or mechanical pressing) of the oil. It was reported that castor oil obtained from the cold pressing method has low acid value, low iodine value, lighter colour and slightly higher saponification value compared to the solvent extracted oil [6].

Castor oil is used to make soap, sulfated castor oil is used to manufacture detergent, and other forms of the oil are important for the treatment of leather to wet band disperse dyes, pigment, fillers, industrial lubricants and other industrial uses like resins, waxes, polymers etc. [7-9]. Castor oil had been used in the production of biodiesel as a source of alternative energy source [10-13]. Castor oil is regarded as one of the most valuable laxatives in medicine.

Castor oil has versatile applications in various industrial sectors and it has also been noted that the oil differs according to geographical locations in which the plant is grown. Hence, the aim of this study was to carry out comparative study on proximate, elemental and physicochemical characteristics of the castor oil from three different state capitals South Western Nigeria.

2. Materials and Methods

2.1. Castor Seeds Collection and Its Pretreatment

Castor seeds were collected from three different states in South Western, Nigeria. The samples were purchased from Tewure market at Ogbomoso town in Oyo State, Osogbo market in Osun State and Oja-Oba market in Akure, Ondo State. It was taken to the botanist of the Environmental Biology Unit of Science Laboratory Technology Department, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria for identification. Thereafter, it was taken to the laboratory for sorting, cleaning, oven drying and milling into pastry form for extraction.

2.2. Quality Control and Assuarance

All chemicals used were of analytical grade (99% purity). Distilled water was used for the preparation of reagents. De-ionized water was used for elemental analyses. Laboratory apparatuses were washed with detergent, rinsed with distilled water and oven-dry before use. Samples were analysed in triplicates.

2.3. Extraction and Percentage Yield Determination of Castor Oil

This was carried out by method described by Muzenda *et al*. [14]. The milled sample of known weight was put into a sieve and then inserted into the extractor pan. It was pressed using a hydraulic press in the Food Science and Technology processing laboratory of the institution at room temperature without heat (25°C). The oil was further filtered and poured into a plastic beaker for laboratory analysis.

The % yield was calculated as: $\% Yield = \frac{X_1 - X_2}{X_1} \times 100$

Where: X_1 = weight of the castor sample before pressing and X_2 = weight of the castor sample after pressing.

2.4. Proximate Analysis

Proximate analysis of the castor seed was determined using standard analytical methods described by official methods of Association of Analytical Chemists [15]. Carbohydrate was calculated by difference.

2.4.1. Moisture Content

5g of the grounded castor seeds sample was weighed into a glass petri dish and dried in an oven at 105°C for 5hrs and the weight was taken after every 2hours until a constant weight was achieved. The sample placed in the desiccator for 30 minutes to cool. It was then removed and re-weighed. The percentage moisture in the seed was calculated.

$$\% Moisture\ Content = \frac{W_2 - W_1}{W_1} \times 100$$

Where W_1 = Original weight of the sample before drying; W_2 = Weight of the sample after drying.

2.4.2. Fat Content

The thimble was washed, previously dried (W_1), it should be fat free. Enough sample was added into the thimble and weigh again (W_2), 500ml round bottom flask was weighed (fat free) W_3. The soxhlet extractor was set up with a reflux condenser. The heat source is adjust so that the solvent boils gently, and was left to siphon over several hours (5 - 6 hours). Finally, wait until the petroleum ether has just siphoned over the barrel. The condenser was detached and removes the thimble or filter paper distils petroleum ether from the flask. The flask containing the fat residue was dried in an air oven at 100°C for few minutes or on water bath and was allow to cool in desiccator and weighed (W_4).

$$\% Fat = \frac{W_4 - W_3}{W_2 - W_1} \times 100$$

2.5. Elemental Analysis

Elemental determination was carried out according to standard method [15]. Atomic Absorption Spectrophotometer (AAS) Buck Scientific 210 VGP equipment was used for the determination of Cd, Pb, Co, As, Ni, Cu, Fe, Mn, Zn, Mg while Na, K and Ca were determined using Buck Scientific Flame Photometer FP 902 equipment.

2.6. Physicochemical Analysis of the Extracted Oil

The refractive index of the extracted oil was determined using Abbe refractometer at 25 ^{o}C and the specific gravity

was determined gravimetrically [15]. Acid value (AV) and free fatty acid (FFA) were determined according to International Union of Pure and Applied Chemistry [16]. Iodine value (IV), saponification value (SV), unsaponifiable matter (UM) and peroxide value were determined according to AOAC [15].

2.6.1. Refractive Index

Abbe refractometer was used to determine the refractive index. Few drops of the sample were transferred into the glass slide of the refractometer. Water at 30°C was circulated round the glass slide to keep its temperature uniform. Readings were viewed through the eyepiece of the refractometer. The dark portion view was adjusted to be in line with the intersection of the cross. At no parallax error, the pointer on the scale pointed to the refractive index. This was repeated and the mean value recorded as the refractive index.

2.6.2. Specific Gravity

Density bottle was used to determining the density of the oil. A clean and dry density bottle of 25ml capacity was used and weighed (Wo). The density bottle was then filled with the oil, stopper inserted and reweighed to give (W_1). The oil was substituted with water after washing and drying the bottle and weighed to give (W_2). The expression for specific gravity (SG) is:

$$SG = \frac{W_1 - W_0}{W_2 - W_0} = \frac{\text{Mass of oil}}{\text{Mass of equal volume of water}}$$

2.6.3. Free Fatty Acid and Acid Value

Two grams of sample was accurately weighed into a 250 mL conical flask; 10 mL of the neutralized 95% ethanol and 2 drops of phenolphthalein indicator were added. This mixture was titrated with 0.10M KOH solution with constant shaking until a pink colour persisited for 30 seconds.

$$\text{FFA (\% Oleic acid)} = \frac{\text{Titre Value} \quad \text{Molarity of KOH} \quad 28.2}{\text{Weight of oil Sample}}$$

$$\text{Acid Value (mg KOH/g Oil)} = \frac{\text{Titre Value} \quad \text{Molarity of KOH} \quad 56.11}{\text{Weight of oil Sample}}$$

2.6.4. Iodine Value

5.00g of the oil sample was treated with an excess of iodobromine (IBr) in glacial acetic acid. Unreacted iodobromine is reacted with potassium iodide which converts it to iodine. The iodine concentration is then determined by titration with standard sodium thiosulphate.

$$IV = \frac{(b - v) \times N \times 126.9 \times 100}{Weight\ of\ oil\ sample}$$

where b is the quantity of sodium thiosulphate used for blank, v is the quantity of thiosulphate for sample, N is the normality of thiosulphate solution, w is the weight of the oil sample and 126.9 is the molecular weight of iodine [17].

2.6.5. Saponification Value

The saponification value is determined by taking 1.0 g of the oil sample into a conical flask to which 15 mL 1 N KOH and 10 mL of distilled water were added and heated under a reserved condenser for 30–40 minutes in order to ensure that the sample dissolved properly. After this, the sample was allowed to cool down. Phenolphthalein was added as indicator and titrated with 0.5 M of HCl until a pink endpoint was reached. A blank was determined with the same time and conditions.

2.6.6. Unsaponifiable Matter

A modified method by Hartman [18] was used for the determination of unsaponifiable matter in oil samples. 2.5 g sample of oil with 2 M ethanolic potassium hydroxide solution, dissolving the resultant mixture in 50 mL of pure cyclohexane, removing the soap by addition of 25 ml of water containing 0.5 g of sodium hydrogencarbonate and extracting the separated soap layer with 25 ml of cyclohexane. The combined cyclohexane layers are washed twice with 25 mL portions of 50% aqueous ethanol, cyclohexane is evaporated and the residue is dried at 80°C.

$$\text{unsaponifiable matter (\%)} = \frac{m_1 - m_2}{m} \times 100$$

Where m_1 is the mass of the dry residue (g), m_2 is the mass of the residue obtained with the blank (g) and m is the mass of the oil sample weighed.

2.6.7. Peroxide Value

Peroxide (PV) is determined by measuring iodine released from potassium iodide. A known measured weight of the oil sample is dissolved in acetic acid then chloroform and saturated potassium iodide (KI) mixture are added to the sample and the amount of iodine liberated from KI by the oxidative action of peroxides present in the oil is determined by titration with standard sodium thiosulphate using starch solution as an indicator. Titration was also performed for the blanks.

$$PV\left(\frac{Meq O_2}{kg} oil\right) = \frac{(A - B) \times N \times 1000}{Weight\ of\ oil\ sample}$$

Where: A is the volume of sodium thiosulphate used for blank, W is the weight of sample, A is the volume of sodium thiosulphate consumed by the sample oil and N is the normality of standard sodium thiosulphate [19].

2.6.8. Determination of pH Value

10g of the sample was poured into a clean dry 200mL beaker and 100mL of hot distilled water was added to the sample in the beaker and stirred slowly. It was allowed to cool down to 25°C. The pH meter was calibrated using standardized buffer solutions and the electrode immersed into the sample while the pH value was read and recorded.

2.7. Statistical Analysis

The statistical analysis was performed using statistical package for social scientist (SPSS) version 16.00. Data obtained were determined in triplicate and expressed as mean

± standard deviation (SD) and statistical significance was assigned at $p<0.05$ levels [20].

3. Results and Discussion

3.1. Proximate

Table 1. *Proximate composition of castor seed collected from three state capitals in South Western Nigeria.*

Sample/Parameter	Ogbomoso	Osogbo	Akure
% Moisture Content	6.02±0.01[a]	6.02±0.01[a]	6.02±0.01[a]
% Fat Content	67.41±0.01[a]	67.32±0.03[b]	67.22±0.02[c]
% Ash Content	3.17±0.03[a]	3.13±0.01[ab]	3.08±0.02[b]
% Protein Content	15.23±0.04[a]	15.22±0.02[a]	15.13±0.04[a]
% Fibre Content	2.32±0.02[a]	2.33±0.04[a]	2.26±0.02[a]
% CHO Content	5.95±0.03[a]	5.94±0.02[a]	5.88±0.01[a]

Note: Results are expressed as means ± standard deviation (n=3). Values with different superscripts in each row are significantly different (P< 0.05).; CHO – Carbohydrate

The proximate composition of castor seed samples collected from three different state capitals in South Western, Nigeria was presented in Table 1. The moisture content of castor seed collected from Ogbomoso, Osogbo and Akure were the same (6.02±0.01). High moisture content in agricultural produce promotes microbial growth and spoilage [22] and it provides medium for many reactions such as hydrolytic rancidity of foods containing lipids. High fat content was recorded from Ogbomoso sample with the value of 67.41%, followed by that from Osogbo 67.32% while sample from Akure was the lowest 67.22%. There is significant difference at $p<0.05$ in the % fat content from the states. The ash content of sample from Ogbomoso was 3.17%, sample collected from Osogbo was 3.13% and sample from Akure was 3.00%. Ash content of samples from locations Ogbomoso and Akure differs significantly at $p<0.05$% level, while there is no significant difference between the ash content of samples from locations Ogbomoso and Osogbo. Ash content presents the total mineral constituents of food stuff. The % protein contents were 15.23%, 15.22% and 15.13% for castor bean seed from locations Ogbomoso, Osogbo and Akure respectively. The % fibre content of sample from Osogbo was 2.33% while that of Ogbomoso was 2.22% and 2.26% for sample from Akure. Carbohydrate content of samples from the three locations were 5.95% (Ogbomoso), 5.94% (Osogbo) and 5.88% (Akure) respectively. There is no significant difference at $p<0.05$% from the three locations as far as the protein, fibre and carbohydrate content are concern.

3.2. Chemical and Physical Composition of Castor Oil

The physicochemical composition of castor seed oil collected from three different state capitals in South Western Nigeria and ASTM standard [21] for some parameters were presented in Table 2. The acid value of the castor oil from Ogbomoso, Osogbo and Akure were 7.72±0.02, 7.71±0.01 and 7.72±0.02 respectively. There is no significant difference in the AV from the three locations. This value was higher than 2.07 mg KOH/g reported by Yusuf *et al.* [23] of castor seed oil from Kastina, Nigeria and 4.90 mg/g reported by Salimon *et al.* [24] of Malaysian castor bean. Acid value of 1.469mgKOH/g was reported by Abdulrasheed *et al.*[7]. ASTM standard for acid value is 0.4 - 4.0 mgKOH/g. The difference might be due to quality of the oil and other factors such as soil quality and location. Acid value is a measure of the FFA content of oil. The FFA was 3.86±0.01, 3.81±0.01 and 3.74±0.05 for Ogbomoso, Osogbo and Akure. %FFA of 3.40 was reported of Malaysian castor seed oil by Salimon *et al.,*[24] and 1.035 by Yusuf *et al.,* [23]. There is no significant difference between sample from Ogbomoso and Osogbo, but result of FFA of sample from Akure significantly differ from the other two locations. The peroxide values (PV) were 0.03±0.00, 0.03±0.00 and 0.02±0.00 for locations Ogbomoso, Osogbo and Akure. PV did not differ at $p<0.05$ level. PV of 10.20meq/kg was reported of Malaysian castor seed oil by Salimon *et al.,* [24] and 38.00 by Yusuf *et al.,* [23] of castor oil from Kastina, Nigeria while Nangbes *et al.*[25] reported 158.640±2.20meq/kg of castor seed oil from Plateau State. Peroxide value is a measure of the degree of rancidity and quality stability indicator of oil; the lower the PV the better the oil quality [26-28].

Table 2. *Physicochemical composition of castor oil samples.*

Sample/Parameter	Ogbomoso	Osogbo	Akure	Std. (ASTM)[21]
Acid Value (mgKOH/g)	7.72±0.03[a]	7.71±0.01[a]	7.72±0.02[a]	0.4 – 4
Free Fatty Acid (% Oleic acid)	3.86±0.01[a]	3.81±0.01[ab]	3.74±0.05[c]	-
Peroxide Value ($MeqO_2$/Kg)	0.03±0.00[a]	0.03±0.00 [a]	0.02±0.00 [a]	-
Specific Gravity (25°C)	0.62±0.03[a]	0.61±0.01[a]	0.61±0.01[a]	0.957-0.968
Colour	Amber	Amber	Amber	-
Refractive index (25°C)	1.21±0.01[a]	1.22±0.02[a]	1.16±0.03[a]	1.476-1.479
Saponification Value (mgKOH/g oil)	124.00±0.00[a]	122.00±0.00[b]	120±0.00[b]	175-187
Unsaponification Value (mgKOH/g oil)	1.01±0.01[a]	1.00±0.00[a]	0.09±0.01[b]	0.3-0.70
Extraction Yield (%)	40.10±0.02[a]	39.80±0.03[b]	37.50±0.05[c]	-
Ph	5.96±0.01[a]	6.02±0.01 [a]	6.08±0.02[a]	-

Results are expressed as means ± standard deviation (n=3). Values with different superscripts in each row are significantly different (P< 0.05). Std. - Standard

The specific gravity of sample from Ogbomoso was 0.62, 0.61 for Osogbo and 0.61 for Akure sample. There is no significant difference in the values of the specific gravity. Yusuf *et al*.[23] reported 0.959 of wild castor seed oil. The

colour of the castor bean oil was the same (amber colour) for the three locations. Oils with lower values of viscosity and density are highly appreciated by consumers. Colour of edible oils is an important physical quality indicator that influences consumer decision about their acceptability [28]. The most acceptable colour of edible oils is golden yellow and the lower the colour unit, the more acceptable and attractive the oil becomes [29].

There is no significant difference in the refractive index values from the three locations. The refractive indexes were 1.21, 1.22 and 1.16 for Ogbomoso, Osogbo and Akure respectively. The saponification value (SV) for sample from Ogbomosho was the highest 124.00mg KOH/g followed by sample collected from Oshogbo 122.00 mg KOH/g and 120.00 mg KOH/g for Akure sample. ASTM standard [21] for SV is 175-187 mg KOH/g. Saponification value is an index of average molecular mass of fatty acid in the oil sample, lower value implies that the mean molecular mass of the fatty acid is lower, which suggest that the fatty molecules did not react with each other [24]. The unsaponification value (UV) was 1.01 for sample collected from Ogbomoso, 1.00 for sample from Osogbo and 0.09 for sample from Akure. There is no significant difference in the UV between samples from Ogbomoso and Osogbo, but there is significant difference in the UV of Akure and the other two locations. The pH of the oil from the three locations does not differ significantly from one another. pH was 5.96 for Ogbomoso, 6.02 for Osogbo and 6.08 for Akure. Akpan *et al.,* [30] reported 6.11 for crude castor oil and 6.34 for refined castor oil. pH provides information about the degree of acidity or alkalinity of samples and for various areas of their application.

3.3. Elemental Composition of Castor Seed

Table 3. *Elemental composition of castor seed samples collected from three state capitals in South Western, Nigeria.*

Sample/Parameter (mg/100g)	Ogbomoso	Osogbo	Akure
Sodium (Na)	20.60±0.00^{a}	20.10±0.00^{b}	19.60±0.00^{c}
Potassium (K)	53.20±0.00^{a}	52.70±0.00^{b}	52.20±0.00^{c}
Calcium (Ca)	62.50±0.00^{a}	62.00±0.00^{b}	61.50±0.00^{c}
Magnesium (Mg)	0.756±0.03^{a}	0.752±0.02^{ab}	0.746±0.04^{b}
Zinc (Zn)	0.311±0.01^{a}	0.305±0.03^{ab}	0.301±0.01^{b}
Iron (Fe)	0.481±0.01^{a}	0.476±0.01^{b}	0.471±0.01^{c}
Copper (Cu)	0.152±0.02^{a}	0.143±0.04^{b}	0.141±0.01^{b}
Cadmium (Cd)	0.001±0.00	0.000±0.00	0.000±0.00
Nickel (Ni)	0.000±0.00	0.000±0.00	0.000±0.00
Lead (Pb)	0.007±0.00	0.002±0.00	0.000±0.00
Cobalt (Co)	0.000±0.00	0.000±0.00	0.000±0.00
Arsenic (As)	0.000±0.00	0.001±0.00	0.000±0.00

Results are expressed as means ± standard deviation (n=3). Values with different superscripts in each row are significantly different (P< 0.05).

The mineral and heavy metals composition of castor seed collected from three different states were presented in Table 3. The minerals include Na, K, Ca, Mg, Zn and Fe while heavy metals analysed were Cu, Cd, Ni, Pb, Co and As.

The value of sodium (Na) concentration of the castor seed collected from Ogbomoso, Osogbo and Akure were was 20.600±0.00mg/100g, 20.10±0.00 and 19.60±0.00 while sample collected from Osogbo was 20.100±0.00mg/100g and sample from Akure was 19.600±0.00mg/100g. The highest concentration of potassium (K) was recorded from Ogbomoso with the value of 53.200±0.00mg/100g followed by Osogbo with the value of 52.700±0.00mg/100g and the least was 52.200±0.00mg/100g from Akure. Calcium (Ca) concentration was 62.500±0.00mg/100g, 62.000±0.00mg/100g and 61.500±0.00mg/100g for sample from Ogbomoso, Osogbo and Akure respectively. There is significant difference in Na, K and Ca concentrations at $p<0.05$ level from the three locations. Ogbomoso has the highest value followed by Osogbo and Akure the least concentrations for Na, K and Ca. The Magnesium (Mg) concentration was 0.756±0.03mg/100g for sample collected from Ogbomoso 0.752±0.02mg/100g was for Osogbo while 0.746±0.04mg/100g was for sample collected from Akure. Zinc (Zn) concentration from Ogbomoso was the highest (0.311±0.01mg/100g), followed by location Osogbo (0.305±0.03mg/100g) and location Akure was the least (0.301±0.01mg/100g). There is significant difference in the Mg and Zn concentrations between location Ogbomoso and Akure, but there is no significant difference between that of locations ogbomoso and Osogbo at $p<0.05$ significant level. The concentration of copper was 0.152±0.02mg/100g, 0.143±0.04mg/100g and 0.141±0.01mg/100g for castor seed samples from locations Ogbomoso, Osogbo and Akure respectively. There is significant difference in the Cu concentrations between locations Ogbomoso and Osogbo, but no significant difference between samples from Osogbo and Akure. Cu and Zn are essential trace elements needed in small quantity for biochemical functions in human body. Iron (Fe) concentrations were 0.481±0.01mg/100g, 0.476±0.01mg/100g and 0.471±0.01mg for samples from locations ogbomoso, Osogbo and Akure respectively. The Fe concentrations from the three locations differ significantly at $p<0.05$ level. The concentration of lead (Pb) was 0.007±0.00mg/100g for Ogbomoso, 0.002±0.00mg/100g for location Osogbo and 0.000±0.00 mg/100g for location Akure. The concentrations of Cd, As, Ni and Co were below detection limits of the equipment; hence they all read 0.000 mg/100g.

4. Conclusion

There was significant difference in the proximate composition of castor seed from the three locations. Sample from Ogbomoso has the best quality in terms of proximate composition. The physicochemical compositions of the castor oil from the three locations were of no significant difference in terms of their quality. Sample from Ogbomoso had the best mineral composition. Samples from the three locations were free from heavy metals. Sample from Ogbomoso had the highest extraction yield.

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