NIPES

Journal of Science and Technology Research

Journal homepage: www.nipesjournals.org.ng

Characterization of castor seed oil extracted from the seed species native to Edo State, Nigeria

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ARTICLE INFORMATION

Article history:
Received 22 February 2019
Revised 07 March 2019
Accepted 16 March 2019
Available online 25 March 2019

Keywords:
Physico-chemical Characteristics
Castor seed oil
Industrial applications
Cold-pressed

ABSTRACT

Researchers have shown some concern over the use of castor seeds in the preparation of local food condiment and the suitability of the oil quality in diverse industrial applications. In Nigeria currently, there appears to be little effort on the commercial cultivation and extraction of castor seed oil to harness the economic potential inherent in the plant. This study seeks to evaluate the physicochemical characteristics of castor seed oil keeping in view the versatile applications of the oil in cosmetic, pharmaceutical, paints, varnishes, lubricants and recently as renewable source. The oil from castor seed obtained from Edo State, Nigeria was extracted using a mechanically cold pressed method. The yield of the oil from the Castor seed is 40%. The physical parameters of the seeds such as moisture content, ash content and linear dimensions like length, width and thickness were studied and found to be 0.32%, 6.44%, 12.02 mm, 8.20 mm and 5.06 mm, respectively. The physico-chemical analysis of the oil showed viscosity of 0.413 cP @ 30^0C, pH of 5.50, saponification value of 184.6 mg KOH g^{-1}, iodine value of 87.94g$I_2$100g^{-1}, acid value of 5.92 mg KOH g^{-1}, specific gravity of 0.968 g/cm^3, refractive index of 1.477 @ 27.4^0C, free fatty acid of 2.98% and peroxide value of 157.82 Meq/kg. The extraction yield of 40% obtained makes the commercialization of the seed in Nigeria feasible and profitable. The result of the analysis also confirms the oil to be of good quality and can find application in food industry as food additives as well as for industrial purposes.

1. Introduction

Castor oil plant is a species of flowering plant in the Spurge family, Euphorbiaceae. It is the sole species in the monotypic genus, Ricinus, and subtribe, Ricininae. Its seed is the castor bean, which despite its name, is not a true bean. Castor bean, the single member of the African genus *Ricinus*, presents a wide variation regarding vegetative traits such as leaf and stem colors, number and size of leaf lobes and the presence of wax covering the stem. Castor is indigenous to the southeastern Mediterranean Basin, Eastern Africa and India, but is widespread throughout tropical regions and widely grown elsewhere as an ornamental plant. Oils that are extracted from plants have been used in this world since the ancient times and already used in many cultures. The castor seed plant has been known to man for ages. Although the plant has migrated across the world, the castor bean shrub originated in Africa and grows wild in East and North Africa, the Yemen and the Near and Middle East. It was cultivated in Ancient Egypt as far back as 4000B.C. and during that time, the castor oil was used thousands of years ago in the wick lamps for lighting. Basically, there is a growing interest in castor oil plant owing to the desirable qualities of its oil. Castor oil is pale yellow, non-volatile, viscous and nondrying in nature [1]. The oil consists of unique fatty acid, ricinoleic acid which

comprises 90% of the total fatty acids. Other fatty acids include palmitic 0.7%, oleic 2.8%, linoleic 4.4%, and linolenic acid 0.2% [2, 3]. Ricinoleic acid is chemically known as 12-hydroxy-9-octadecenoic acid. The castor plant grows in the wild in large quantities in most tropical and sub-tropical countries. It is available at the low price and known to adapt to varying climatic conditions. Normally, the castor plant needs temperature between 20 and 26 °C with low humidity throughout the growing season in order to give maximum yield. Moreover, the weather conditions for its growth limit its cultivation to tropical areas of the developing world. There are different types of castor seeds all around the world but on the average, the castor seeds contain about 30 to 55% of oil by weight. The seeds are very poisonous to human and also animals as the seeds contain ricin, ricinine and certain allergens which are toxics. However, in certain cultures, the seed is used as food condiment after a four-day fermentation period [4, 5, 6]. The effects if the castor seed is accidentally ingested, the victims will face abdominal pain, vomiting and diarrhea and as little as 1 mg of the ricin can bring the human to death. The fear of accidental ingestion of the poisonous castor seed by the children does not encourage the use of the castor plant for ornamental purpose. The industrial potential of castor oil relies on its high content of ricinoleic acid. Based on its industrial potential and the role it actually plays in sub-Saharan area not only in human medicine, but also in reduction of desert progression, castor bean may play a role in poverty alleviation in rural areas, but the data on their oil and fatty acid contents are very scarce. In addition there is limited information on the valorization of the cake, a by-product that derived from castor oil extraction.

Research interest on castor seed oil physicochemical properties has built up in recent time. Some of the past research works include Clautilde *et al*. [7] who assessed the physico-chemical properties of oil and cake from seeds of three accessions of castor plant from Sudano-sahelian and Sudano-guinean zones of Cameroon. Udoh *et al*. [8] carried out four accessions of castor (Ricinus communis) grown in Botanical Garden of the University of Nigeria, Nsukka in the derived savanna of southeastern Nigeria for two cropping seasons (2013 and 2014) in a randomized complete block design. The physicochemical analysis of the study showed that castor seed and its oil had saponification value of 182.9 mg/g, moisture content of 4.4%, acid value of 3.085 mg/g, viscosity of 110.41 cP, pH of 6.11, iodine value of 8.46 mg/g, specific gravity of 0.962 and refractive index of 1.477˚C. Warra [9] carried out the physico-chemical and GC/MS analysis of Castor Bean (Ricinus communis L.) seed oil. The physicochemical analysis showed saponification, iodine and acid values of 123.3 ± 3.428 mgKOH/g , 76.93 ± 0.397g I2/100g and 2.39 ±0.065 mgKOH/g respectively. The Major fatty acids derived from the castor bean oil as indicated by the GC-MS results were Oleic acid ($C_{18}H_{34}O_2$), Palmitic acid ($C_{16}H_{32}O_2$), Stearic acid ($C_{18}H_{32}O_2$) , Undecylenic acid ($C_{11}H_{20}O_2$), Methyl ricinoleate ($C_{19}H_{36}O_3$), Behenic acid ($C_{23}H_{46}O_2$), Tridecylic acid ($CH_3(CH_2)_{11}COOH$), Nonadecanoic acid($CH_3(CH_2)_{17}COOH$). Arawande and Akinnusotu [10] investigated the comparative studies of proximate, elemental and physicochemical characteristics of castor seed and oil collected from Ogbomoso in Oyo, Osogbo in Osun and Akure in Ondo States of Western Nigeria. The extracted oil obtained from the castor seeds from each state was also analysed for physicochemical properties. The proximate analysis showed: % fat of (67.41±0.01- 67.22±0.02), % ash of (3.17±0.0-3.08±0.02), % protein of (15.23±0.04-15.13±0.04). The physicochemical analyses revealed: % free fatty acid (FFA) to be 3.86±0.01-3.74±0.05, % specific gravity (SG) to be 0.62±0.03-0.61±0.01 and saponification value (SV) of 124.00±0.00-120.00±0.00 mgKOH/g. The % oil yield ranged between 40.10±0.02-37.50±0.05. Similar studies in this area include: [11, 12, 13, 14, and 15].

It is obvious from the literature review that there appears to be a dearth of research information on the physicochemical characteristics of castor seed oil from Edo State, Nigeria. The aim of this study therefore is to determine the physicochemical characteristics of crude castor seed oil extracted from the seed species native to Edo State, Nigeria since such information may be virtually unavailable.

2. Materials and Method

2.1. Reagents and Castor Seeds Collection

The castor seeds used in this research are castor oil bean seeds- *Ricinus Communis* obtained from a farmland in Ikokogbe, Omhen in Ewossa Community, Igueben Local Government Area of Edo State, Nigeria. The harvested ripe castor fruits were cleaned and sun-dried for 5 days, until fruit capsules split open to discharge encased seeds. This was followed by seed pod removal and tray-winnowing to separate shells from beans (cotyledons). The castor beans were later dried (per 100g sample) at 80^0C to constant weight for 9hrs in a hot air oven. The beans were then grinded to a paste using mortar and pestle, prior to extraction. All chemicals and reagents used in this study was analytical grade from Sigma Aldrich which was used without any further purification. Distilled water was used for the preparation of reagents. Laboratory apparatuses were washed with detergent, rinsed with distilled water and oven-dry before use.

2.2. Extraction of Castor Oil

Castor bean paste was wrapped in clean white cloth and mechanically cold-pressed at 60^0C using a manual machine extractor to obtain clear, viscous, pale-yellow virgin oil. No heat is required and certainly, no chemicals are used in the extraction process. 28g in weight of castor bean paste yielded 10 litres of the virgin oil. The percentage yield of the oil was determined by using the expression described by.

$$\%\,\text{Oil yield} = \frac{y_1 - y_2}{y_1} \times 100 \quad (1)$$

Where y_1 and y_2 are the weights of castor beans before and after the extraction.

After settling for about 1 hour, good quality cold-pressed oil was further purified by filtration through sintered glass (fine mesh screen) in a Buchner funnel. This was to eliminate any dust, gum or other particles present. The purified oil was kept in tightly stoppered dark bottles and stored in a refrigerator at 40C.

2.3 Physical Characteristics of Castor seed

The individual dimension of castor seed such as, length, width, height, individual seed weight and 100 seeds weight was determined and represented in Table 1. The seeds weight was weighed by a sensitive weighing machine with 0.001 sensitivity. Length, width and thickness are measured using micrometer gauge reading of 0.01 mm sensitivity.

Table 1: Castor Seed Physical Characteristics

Parameters	Result
Moisture content %	0.32
Ash Content %	6.24
Length (mm)	12.02
Width (mm)	8.20
Thickness (mm)	5.06
Individual seed weight (g)	0.22
100 seed weight (g)	23.25

Figure 1: Castor seed

2.4 Determination of Castor Seed Oil Physical Parameters

2.4.1. Specific Gravity

The specific gravity of the castor oil sample was determined using a 50 ml capacity density bottle at 30 °C. The density bottle was weighed empty and then filled with the oil sample up to the mark on the bottle. The bottle with castor oil sample was weighed again and recorded. The weight of the empty bottle was subtracted from the total weight of the bottle and oil sample. The weight of the castor oil sample was then divided by the weight of an equal volume of water to obtain the specific gravity (SG) of the castor oil sample.

$$Specific\ \text{Gravity} = \frac{Weight\ \text{of specific volume of oil sample}}{\text{Weight of equal volume of distilled water}} \quad (2)$$

2.4.2. Viscosity

A clean, dried Ubbelohde viscometer was used in this study. The sample was filtered through a sintered glass (fine mesh screen) to eliminate dust and other solid materials in the liquid sample. The viscosity meter was charged with the sample by inverting the tube's thinner arm into the liquid sample and suction force drawn up to the upper timing mark of the viscometer, after which the instrument was turned to its normal vertical position. The viscometer was placed into a holder and inserted to a constant temperature bath set at 30˚C. In use, liquid is drawn into the upper bulb by suction, and then allowed to flow down through the capillary into the lower bulb. Two marks (one above and one below the upper bulb) indicate a known volume. The suction force was applied to the thinner arm to draw the sample slightly above the upper timing mark. The afflux time was recorded by timing the flow of the sample as it flowed freely from the upper timing mark to the lower timing mark. The time taken for the level of the liquid to pass between these marks is proportional to the kinematic viscosity. Recordings were taken and using water as a standard, a viscosity for the sample was recorded.

2.4.3. ph

In a dry clean 25 mL beaker, 2 g of castor seed oil sample was placed followed by 13 mL of hot distilled water and the mixture was stirred slowly. The mixture was then cooled in a cold-water bath

to 25˚C. The pH electrode was standardized with buffer solutions (pH 4 and 7) and the electrode immersed into the sample where an average pH of two recordings per sample were recorded.

2.4.4. Refractive Index

Refractive index is the physical attribute of triglyceride measured by the angle through which a beam of light is bent when passing through a thin film of oil. The determination was performed with the use of an Abbe refractometer at 27.4^0C. This instrument measures the index of refraction by measuring the critical angle of total reflection. In this case, a few drops of the samples were transferred into the glass slide of the refractometer. Water at 27.4˚C was circulated round the glass slide to keep its temperature uniform. Through the eyepiece of the refractometer, the dark portion viewed 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. The refractometer was calibrated using distilled water where the refractive index of water at that temperature was obtained. The refractive index obtained was noted and recorded accordingly.

2.4.5 Determination of Moisture Content of the castor Seed oil

About 20 g of a clean castor oil sample was weighed and then dried in the oven at 80˚C for 2 hrs and the weight was recorded. The same procedure was repeated until a constant weight was obtained. After 2 hours, the sample was removed from the oven and placed in the dessicator for 30 minutes to cool then removed and re-weighed. The percentage moisture content in the seeds was calculated from the expression:

$$\%\,\text{Moisture} = \frac{W_1 - W_2}{W_1} \times 100 \qquad (3)$$

Where,

W_1 = original weight of the sample before drying;

W_2 = weight of the sample after drying

2.5. Determination of Chemical Parameters

2.5.1. Iodine Value

The weight of the oil to be taken varies according to its expected iodine value as set out in Table 2.

Table 2: Expected Iodine value with recommended weight of sample

Iodine value expected	Weight to be taken for test (g)
< 5	3.00
5 to 20	1.00
21 to 50	0.40
51 to 100	0.20
101 to 150	0.13
151 to 200	0.10

The Wij's method was used to determine the iodine value of the oil. The appropriate quantity (0.2g) of the castor seed oil sample was weighed and dissolved in 15 ml carbon tetrachloride and shaken thoroughly in a stoppered round-necked flask. Exactly 25 ml of Wij's solution was added. The flask was stoppered, shaken gently and placed in the dark for 1 hour. At the end of this time, 20 ml of the 10 % (w/v) potassium iodide solution and 150 ml of distilled water were added to the mixture. The mixture was then titrated with an already standardised 0.1 M sodium thiosulphate solution using freshly prepared 1 % (w/v) starch solution as indicator. Starch was added to the mixture as indicator

when it has turned to pale yellow. After the addition of starch, continuing the titration until the blue colour disappeared after very vigorous shaking. A blank determination was then carried out under the similar conditions. The volumes of sodium thiosulphate consumed were recorded. The iodine value (IV) was calculated by the expression:

$$IV = \frac{12.69 \times M \times (V_B - V_T)}{W} \quad (4)$$

Where,

VB = volume (ml) of standardised sodium thiosulphate solution used for the blank test,
VT = volume (ml) of the standardized sodium thiosulphate solution used for the sample,
M = exact normality of sodium thiosulphate solution used,
W = weight (g) of sample.

2.5.2. Acid Value

The acid value of the oil samples were determined by titration method. 2 grams of the castor seed oil was dissolved in 50ml of neutralized solvent of equal volume of diethylether and absolute ethanol. The resultant solution was titrated with standardized 0.1M potassium hydroxide solution using phenolphthalein as indicator. The acid value (AV) was calculated using the following expression:

$$Acid \text{ Value (AV)} = \frac{56.1 \times M \times V}{W} \quad (5)$$

Where:
M = molarity of standard potassium hydroxide KOH
V = volume (ml) of standardized 0.1 M potassium hydroxide consumed by sample,
W = weight (g) of castor oil sample in grams.

2.5.3. Peroxide Value

1 g of sample was dissolve in 25 ml of mixed solvent of 2:1 volumes of glacial acetic acid and chloroform. The air above the liquid is displaced with carbon dioxide. 1 ml of (4 parts of pinch potassium iodine in 3 parts of distilled water) potassium iodide solution was added , stoppered, thoroughly mixed and allowed to stand for one minute. 35ml of distilled water was added to the solution and this was titrated with 0.002M sodium thiosulphate solution using starch solution as indicator. A blank determination was simultaneously carried out. The peroxide value (PV) was calculated by the expression:

$$PV = \frac{1000 \times M \times (V_T - V_B)}{W} \quad (6)$$

Where,

W is the weight in grams of samples,
T is the volume (in ml) of sodium thiosulphate solution used in test
V_B is the volume (in ml) of sodium thiosulphate solution used in blank
M is the molarity of sodium thiosulpahte solution

2.5.4. Saponification Value

5 g of castor seed oil sample was weighed into a 250 ml round-bottom flask and then 50 ml of 0.5M ethanolic potassium hydroxide solution was added. A reflux condenser was connected to the flask and boiled gently on a steam bath, but steadily, until the sample is completely saponified. Intermittent swirling was applied when the solution started to boil. The vapour ring in the condenser was prevented from rising to the top of the condenser to avoid loss. This was completed in 30 minutes. The hot saponified solution was titrated against 0.5 M hydrochloric acid using a phenolphthalein indicator to the end point i.e until the pink colour just disappeared. A blank

determination was also conducted simultaneously under the same condition. The volume of 0.5 M hydrochloric acid required was recorded in both titrations. The saponification value (SV) was calculated using the expression:

$$SV = \frac{56.1 \times M \times (V_B - V_T)}{W} \quad (7)$$

Where,

V_B = volume (ml) of 0.5 M required to titrate blank,
V_T = volume (ml) of 0.5 M hydrochloric acid required to titrate sample,
M = molarity of hydrochloric acid solution,
W = weight (g) of samples in used.

2.5.5 Determination of free fatty acid

5 g of the castor seed oil was weighed into a 250 ml conical flask. 50 ml of neutral solvent of equal volume of ethanol and diethylether was added to the oil sample. The solution was titrated against standardised 0.2 M potassium hydroxide solution to a phenolphthalein endpoint. The free fatty acid was calculated by the expression given below:

$$Free \text{ fatty acid (f.f.a)}\% = \frac{VNM}{10W} \quad (8)$$

Where,

W = Weight (in grammes) of sample

V = Volume (in ml) of NaOH solution used

N = Normality of NaOH solution

M = Molecular weight of the fatty acids

A.V = Acid Value

3. Results and Discussion

The results obtained for the castor seed oil physicochemical characterization is as shown in Table 3 and compared with ASTM values.

Table 3: physicochemical properties of castor seed oil.

S/N	Physical and Chemical Properties	Current Results	*ASTM
1	Specific Gravity (g/cm^3) @ 30^{0}C	0.968	0.957-0.968
2	pH	5.50	-
3	Refractive Index @ 27.4^{0}C	1.477	1.470-1.479
4	Viscosity (cps) @ 30^{0}C	0.413	-
5	Iodine Value (Wijj's Value) gI_2 100g^{-1}	87.94	82-88
6	Acid Value (mg KOH g^{-1})	5.92	-
7	Peroxide Value (Meq/kg)	157.82	-
8	Moisture Content	0.32	0.001-2.5
9	Free Fatty Acid	2.98	0.4-4.0
10	Percentage Oil yield (Cold pressed)	40	35 -55
11	Saponification value (mg KOH g^{-1})	184.6	175-187

The result of the physicochemical analysis carried out in this study showed a percentage oil yield of 40% which falls within the range value of 30-55% reported by [13]. This high yield may well be as a result of environmental factors that influence the growth and development of the castor seed. The cold-press method is also known to yield castor oil of light colour, low impurity level and low light absorbance [1]. The specific gravity was obtained as 0.968 which falls favorably within the standard range specified by ASTM. The refractive index was determined as 1.477. This value was an indication of the level of saturation of the castor seed oil. Comparing the experimental result with the ASTM values that ranges from 1.476-1.479 [16], a little difference is noticed. This little difference can be well-thought-out to be within an acceptable experimental error range that can be attributed to the presence of some impurities and other components of the crude castor oil mixture. Hence, the refractive index of the crude castor oil was in agreement with ASTM specification. The low moisture content of 0.32 achieved represents a good shelf life characteristic of the castor seed oil under consideration. A low acid value of 5.92, low iodine value of 87.94, but relatively high saponification of 184.6 values was obtained which is within the range of values 175 to 185 mgKOH/g oil. The high saponification value obtained points to the suitability of the oil for soap manufacture and in cosmetics industries.

Castor oil obtained from cold pressing has low acid value and has higher saponification value compared to the solvent-extracted oil [1]. The low acid value of 5.92 and pH value of 5.50 suggest low free fatty acid (FFA) content in the oil. Besides, castor oil, like all other vegetable oils, has been found to have different physical and chemical properties that vary with the method of extraction. Cold pressed castor oil has low acid value than its solvent extracted counterpart. An acid value of 2.7 for cold pressed oil was reported by [17] and 1.148 by [2]. Other researchers like [18] reported an acid value of 9.7 while 19 was reported by [19] and 14.8 ± 0.14 for hexane extracted castor oil by [20]. The higher the iodine value the higher the reactivity of the oil. The low iodine value observed for the castor seed oil is suggestive of low unsaturation level typical of non-drying oils which showed that the castor seed oil employed is within the non-drying regime since the iodine value is less than 100. For the oil to meet drying properties, it must undergo dehydration. The viscosity was determined at 30^0C using viscometer. The value of 0.413cps obtained shows the viscous nature of the oil. The Peroxide value was gotten to be 157.82 Meq/kg. The high peroxide value of the oil sample clearly shows that the oil is prone to rancidity and thus less stable. It also helps to determine the stability and suitability of the castor oil

4. Conclusion

In this study, the physical characteristics and chemical properties of the castor seed and its oil as well as the procedures adopted have been discussed. The results of the chemical analyses carried out showed that castor seeds possess high nutrients and have necessary abilities to meet the nutritional requirements. The use of castor seeds as food condiment can be justified since the seeds have high nutrients with high potassium content. It can also be deduced that the castor seed oil has potential in the production of cosmetics, perfumery, and pharmaceuticals among others. The result also shows that castor seed oil can be classified as non-drying oil since the iodine value is less than 100, which can be dehydrated to give a drying oil that can be used extensively in paint and vanishes. The most critical factor limiting the use of castor seed as a complementary nutrient is the presence of poisonous ricin content in the seed. However, the seeds have to be subjected to fermentation and properly treated before they can be used either as food condiment or feed for animals.

5. Conflict of Interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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