European Journal of Biophysics
2024, Vol. 12, No. 1, pp. 15-20
https://doi.org/10.11648/j.ejb.20241201.13

Research Article

Fatty Acid Composition and Physicochemical Properties of *Ricinus communis* Seed Oil Grown from Jabi Tehinan Woreda, Ethiopia

Yihalem Abebe Alemayehu*, Fekadu Wubatu Fenta, Yihenew Simegnew Birhan

Department of Chemistry, Debre Markos University, Debre Markos, Ethiopia

Abstract

Castor seed oil is well known for its diverse medicinal and industrial uses. It is widely utilized as an additive in foods, medicine, personal care goods, lubricant and biodiesel. Nonetheless, the oil content and physicochemical properties of castor seeds depend on their genotypic varieties and geographical location. Fortunately, Ethiopia is endowed with varieties of castor seeds. However, there is a limited research on the total oil content and quality of castor seeds oil. Thus, the aim of this study was to examine the total oil content, the physicochemical characteristics and fatty acid composition of castor seeds oil grown in Jabi Tehinan Woreda, Ethiopia. The three most populous genotype castor beans were collected and subjected to soxhlet extraction using hexane solvent. The outcome showed that their genotypes determine both the amount and quality of the oil extracted. Genotype 01 (GT-01) has exceptionally the highest oil content (69.8%) while the Genotype 02 (GT-02) (47.305) and Genotype 03 (GT-03) (43.21%) have high oil contents. GT-01 has the highest (87.49%), GT-02 the second (85.17) and GT-01 (84.01) the third ricinoleic acid component. This high ricinoleic acid composition is reflected on their chemical and physical properties which are in the range of ASTM standards, making them valuable for various industrial applications.

Keywords

Castor Seed Oil, Fatty Acid Composition, Ricinoleic Acid, Physico-chemical Analysis

1. Introduction

The castor bean plant (*Ricinus communis)* also known as Palma Christi or wonder tree reflects the inherent healing power of oil extracted from the beans of the plant. The plant can vary greatly in its growth habit, morphology and uses [1, 2]. Many studies revealed that there are varieties of castor plant seeds with different colors. The seeds may be colored white, dark brownish-red, brown, dark chocolate, red, or black, but usually several colors occur as very attractive mottle on the testa [3].

The diverse industrial and medicinal applications let the castor plant receive great attention in research. The oil extracted from castor bean already has a growing international market, assured by more than 700 uses, ranging from cosmetics and medicines to substituting petroleum in the manufacturing of biodiesel, paints, varnishes, and other protective coatings, bulletproof glass, plastics, artificial leather, soaps,

*Corresponding author: yihalem.abebe@dmu.edu.et (Yihalem Abebe Alemayehu)

Received: 13 February 2024; **Accepted:** 26 March 2024; **Published:** 12 April 2024

printing inks, linoleum, polymers, coatings, hydraulic fluids, manufacture of fiber optics, antifreeze for fuels and lubricants utilized in aircraft and space rockets [4-8]. Its' resistance to drought conditions gives an additional opportunity to increase its exploitation in marginal regions [9].

A large variation of seed oil content was observed, ranging from 39.6% – 59.5% [10, 11]. According to various publications, ricinoleic acid is reported as a major component in castor oil; about 74.10% to 92.3% [12, 13]. Other identified fatty acids include linoleic, oleic, stearic, palmitic, erucic, and eicosadienoic [12]. So the castor oil is a unique natural substance with almost pure composition, a rare natural phenomenon. There are variety caster seeds existed in Ethiopia. However, there are limited discoveries on the physicochemical and fatty acid compositions to explore the possible applications of caster seed oil in industries. Therefore, this study aimed to determine the fatty acid composition and physicochemical properties of oils extracted from three caster seed varieties collected from Jabi Tehinan Woreda, Ethiopia.

2. Materials and Method

2.1. Collection of the Sample and Pre-production Process

Figure 1. *The three different coloured castor seeds (three gynotypes) collected.*

The three different Ricinus communis plant specimens as shown in Figure 1, were collected from Jabitehinan Woreda, Ethiopia. The seeds were sundried from 4-5 days to reduce the moisture content. The de-shelled seeds were further dried at 80 ℃ for 10 hours in an oven. The undamaged seeds samples were grounded to a paste using mortal and pistil before extraction proceeded.

2.2. Oil Extraction Process

About 100g of oven dried and grounded seeds were extracted using hexane as solvent. The samples were refluxed for 6 hours at a mild temperature (55-60 ℃) using a Soxhlet extractor. The solvent was removed by using rotary vacuum evaporator. Then, the extracted oil was kept in an oven at 60 ℃ for 1 hr before accurately weighed, kept in a closed container, and stored in a refrigerator at 4 ℃ for subsequent physicochemical analysis. The percent oil contents of each sample were determined by dividing weights of the extracted oils over weights of the dried samples multiplied by 100%.

$$\% \text{ oil content} = \frac{\text{weight of the oil}}{\text{weight of the dried sample}} \text{ x100\%}$$

2.3. Chemical Analysis

Acid value (AV)

5gm of oil samples were dissolved in 25 mL of absolute ethanol in the conical flasks. Few drops of phenolphthalein indicators were added to the container, the mixture was heated in occasional shaking for few minutes and titrated against 0.1 N KOH until pink color appeared. The volume of 0.1 N KOH consumed by an acid was recorded and the acid value was calculated as reported in the literature [12].

$$\text{A.V} = \frac{56.1 \text{x} V \text{x} N}{m}$$

where V = volume of KOH used; N = normality of KOH and m = mass of sample.

Iodine Value (IV)

To 250 mL conical flask 0.25 g of the oil sample, 10 mL of chloroform followed by 30 mL of Hanus iodine solution were mixed and shacked for 30 minutes in the dark. 10 mL of 15% potassium iodide solution was added, and 100 mL of distilled water was added while shaking the mixture. The mixture was then titrated against 0.1 N Sodium thiosulfate solution till a yellow color formed. A blue solution was noticed after adding 3 drops of starch solution. The titration continued until the blue color was disappeared and the volume of $Na_2S_2O_3$ was recorded at the end point. The Iodine value (I.V) was calculated based on the formula reported [14].

$$I_2 + \text{starch} + 2Na_2S_2O_3 \text{ (blue)} \longrightarrow 2NaI + \text{starch} + Na_2S_4O_6 \text{ (colorless)}$$

$$\text{I.V} = \frac{12.69 \text{x} C \text{x} (V1\text{-}V2)}{m}$$

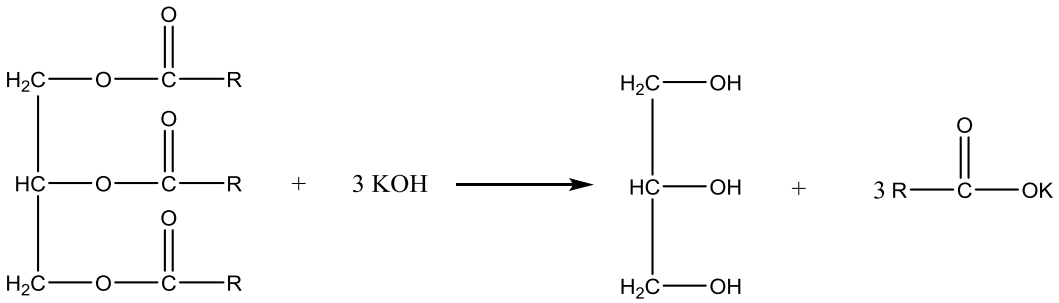
where c = Concentration of $Na_2S_2O_3$ used; V_1 = volume of $Na_2S_2O_3$ used for the blank; V_2 = volume of $Na_2S_2O_3$ used for sample; m = mass of the sample.

Saponification Value (SV)

A 1 g sample of the oil was added into a 250 mL glass conical flask, and then 10 mL of ethanol/ether mixture (2:1) was added to the same flask followed by 25 mL of 0.5 N ethanolic potassium hydroxide to hydrolyze the triglycerides (Scheme 1). Then the flask was refluxed using a boiling water bath for 30 min with occasional shaking. 3 - 4 drops of phenolphthalein indicator were added to the warm solution, and the warm solution was titrated against 0.5 M HCl to the end point. The same procedure was applied for other samples and blank. Then saponification value (S.V) was calculated [15].

$$S.V = \frac{56.1x\ N_{HCl}(V_B - V_S)}{m_S}$$

Where V_B = the volume of the solution used for blank test; V_S = the volume of the solution used for the sample; N = Actual normality of the HCl used; m = Mass of the sample.



Scheme 1. *Hydrolysis of triglycerides in to fatty acids.*

Peroxide Value (PV)

1 g of the oil sample, 1 g of potassium iodide, and 20 mL of solvent mixture (glacial acetic acid/chloroform, 3/2 by volume) were added into a 250 mL Erlenmeyer flask, and the mixture was heated to boiling for one minute. The hot solution was poured into a flask containing 20 mL of 5% potassium iodide followed by 3 drops of starch solution. Then the mixture was titrated with 0.025 N standardized sodium thiosulphate and the peroxide value was determined using the reported equation [14]:

$$P.V = \frac{S \times N \times 100}{w}$$

Where, S = mL of $Na_2S_2O_3$; N = normality of $Na_2S_2O_3$; W = weight of oil sample (g).

2.4. Physical Analysis

pH of 2.30 g dispersion of the oil in 15mL hot water was determined (after cooling to 30 ℃ in a water bath) with the aid of a glass electrode pH meter (HANNA-209-209R).

Refractive index (RI):

The refractive index was measured by dropping oil samples on the glass slide of the refractometer (ATAGO Co. Ltd. Japan) [16].

Specific gravity (SG):

The specific gravities of the oil samples were measured by density bottle. First mass of clean and dry density bottle of 5ml capacity (W0) was measured, then mass of the density bottle was measured after filling with the oil (W1). The measurement was repeated by substituting the oil with water after washing and drying the bottle (W2). Finally, specific gravities of the oils were determined using the equation.

SG = (W1-W0)/(W2-W0) = Mass of the substance / Mass of an equal volume of water [16].

Relative viscosities (RI) of oil samples (in chloroform) were determined at 30 ℃ by an ubbelohde dilution type viscometer with solvent efflux time of 120 seconds.

3. Result and Discussion

3.1. Total Oil Content

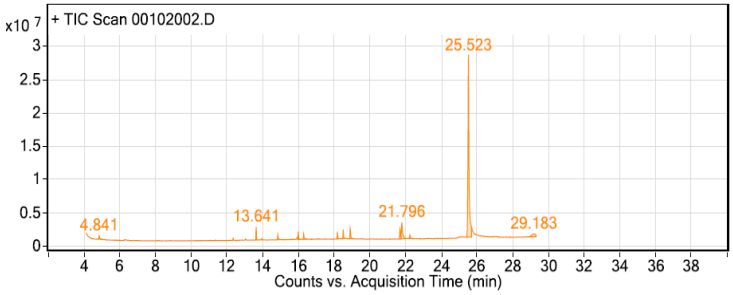
The total oil content of the castor seed oil depends on the class of the genotype. As depicted in Table 1 genotype 01, 02 and 03 gave 69.8%, 47.3% and 43.21% oil content respectively. Thus genotype 01 has exceptionally very high oil content which is not yet reported while the last two have relatively high oil content as reported by different scholars [12, 18].

Table 1. *Characteristics of the three different genotype caster bean oils.*

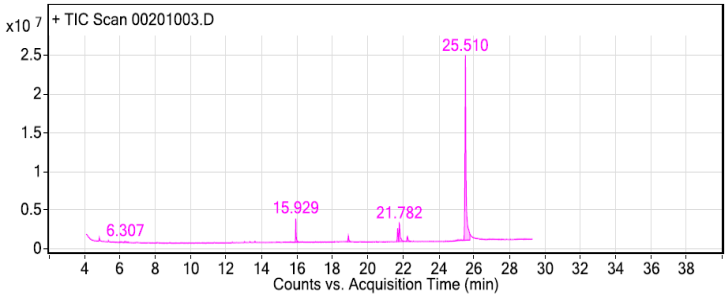
Castor bean type	Mass of the dried Castor bean sample	Mass of the extracted oil	Oil percentage
GT-01	100g	60.98	69.8%
GT-02	100g	40.73	47.30%
GT-03	100g	40.32	43.21%

3.2. Fatty acid Content and Physicochemical Properties

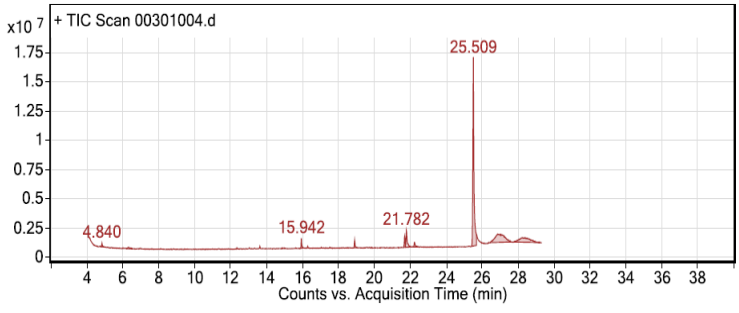
The fatty acid composition of those three samples was determined by comparing their retention times read from each GC chromatogram (Figure 2) with the standards. Ricinoleic acid is the major constituent fatty acid of all genotypes. GT-03 is the highest (87.49%), GT-02 is the second (85.17%) and GT-01 (84.01) is the third in ricinoleic acid composition which is comparable with study conducted in Tanzania [12] but slightly lower than studies in Nigeria and Brazil [17, 18]. Studies in Nigeria and Brazil revealed 90-94% ricinoleic acid component.



(a)



(b)



(c)

Figure 2. *GC chromatogram of GT-01 (a), GT-02 (b) and GT-03 (c).*

According to physicochemical properties results shown in Table 2 GT-01 has highest pH value while GT-02 and GT-03 have relatively lower pH values. The pH values are clear evidences that oils extracted from castor seeds are slightly acidic due to the presence of free fatty acids. The refractive index recorded (GT-01=1.473, GT-02=1.47, GT-03=1.478) from all types of castors seeds are comparable with studies in Tanzania and Malaysia [12, 19]. The specific gravity of all three samples are in the range of ASTM standards (0.957 - 0.968). GT-01 has relatively lowest viscosity (9.24) than GT-02 (9.55) and GT-03 (9.58).

Table 2. *Physio-chemical characteristics of the three different genotype caster bean oils.*

Sample	Physical properties			Chemical properties				
	PH	RI	SG	RV	AV	IV	SV	PV
GT-01	6.21±0.02	1.473±0.01	0.960±0.005	9.24±0.04	3.56±0.03	87.88±1.44	176±5.10	10.21±0.24
GT-02	6.03±0.04	1.470±0.03	0.959±0.001	9.55±0.03	3.05±0.06	86.00±2.65	181±5.33	10.56±0.45
GT-03	5.90±0.02	1.478±0.01	0.967±0.003	9.58±0.07	3.11±0.04	85.7±1.23	179±3.34	11.01±0.11

The chemical properties of the three genotype castor been oil are illustrated in Table 2. The iodine value (IV) of the three genotypes were measured to be less than 100 (GT-01=87.88, GT-02=86.00, GT= 85.70) which made the oil to be classified as non-drying suggested for manufacture of soap [20]. The measured saponification value of the three samples (GT-01, GT-02 GT-03) were 176, 181 and 179 respectively and these values are in the same range as previous studies [12, 21]. The acid values (GT-01= 3.56, GT-02=3.05 and GT-03= 3.11 mg KOH/g oil) are under the range of ASTM specification and lower than previous reports [21, 22]. All the three genotypes show low level of peroxide values which is comparable with the previous reports [21, 22]. This low peroxide values are clear indication of the presence of strong antioxidants that prevent the oils from being spoiled.

4. Conclusion

The physicochemical properties and fatty acid composition of castor seed oils of three genotypes from Jabi Tehinan woreda in north-west Ethiopia have been investigated. The extraction process gave a good yield of the oil contents (GT-01 = 69.8%, GT-02 = 47.30%, GT-02 = 43.21%). The high oil content, proper physiochemical properties and fatty acid composition study of the three different genotype castor seed oils revealed that they have a great potential to be used as raw material in industries like cosmetics, perfume and biodiesel.

Abbreviations

GT: Genotype
mL: milliliter
g: gram
pH: power of hydrogen
GC: Gas Chromtogrphy
ASTM: American Society for Testing and Materials.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Khafagi I. (2007). Variation of callus induction and active metabolite accumulation in callus cultures of two varieties of (Ricinus communis L). Biotechnol. 6: 193-201. https://doi.org/10.3923/biotech.2007.193.201

[2] Christopher B. (1996) "The Royal Horticultural Society A-Z Encyclopedia of Garden Plants," Dorling Kindersley, London, 884-885. A-Z encyclopedia of garden plants: Free Download, Borrow, and Streaming : Internet Archive.

[3] Salihu B., Gana A., Amosun A., Shaahu S., Agboire, B. Apuyor & Oliseh A. (2023). Morphological Characterization of Castor (Ricinus ommunis L.) Accessions. Proc. Agricultural Society of Nigeria. 308-316. https://doi.org/10.3390/agronomy13040985

[4] Cosmetic Ingredient Review Expert Panel (2007). Final Report on the Safety Assessment of Ricinus communis (Castor) seed Oil. International Journal of Toxicol. 26 (suppl. 3): 31-77. https://doi.org/10.1080/10915810701663150

[5] Weiss E. A. (2000) Castor. In "Oilseed Crops, 2nd Edition". Blackwell Scientific Ltd, Oxford: 13-52. https://doi.org/10.1023/A:1013319111776

[6] Jeong, G. & Park, D. (2009). Optimization of Biodiesel Production from Castor Oil Using Response Surface Methodology. Applied Biochemistry and Biotechnology. 156: 431–441. https://doi.org/10.1007/s12010-008-8468-9

[7] Ogunniyi D. (2006). Castor oil: a vital industrial raw material. Bioresources and Technology. 97(9): 1086-1091. https://scialert.net/abstract/?doi=biotech.2017.1.9

[8] Allan G., Williams A., Rabinowicz, P., Chan, A., Ravel J. & Keim, P. (2008). Worldwide genotyping of castor bean germplasm (Ricinus communis L.) using AFLP and SSRs. Genetics Resources and Crop Evolution. 55: 365-378. https://doi.org/10.1007/s10722-007-9244-3

[9] Papazoglou E., Alexopoulou E., Papadopoulos G. & Economou-Antonaka G. (2020). Tolerance to drought and water stress resistance mechanism of castor bean. Agronomy. 10:1580. https://doi.org/10.3390/agronomy10101580

[10] Ramos, L., Tango, J., Savi A. & Leal N. (1984). Variability for Oil and Fatty Acid Composition in Castor Bean Varieties. J. Am. Oil Chem. Soc. 61: 1841-1843. https://doi.org/10.1007/BF02540812

[11] Yadav P. & Anjani K (2017). Assessment of variation in castor genetic resources for oil characteristics. Journal of the American Oil Chemists' Society. 94:611-7. https://doi.org/10.1007/S11746-017-2961-7

[12] Athumani O., Quintino A. Mgani E. & Mubofu B. (5015). Fatty Acid Profile and Physico-Chemical Parameters of Castor Oils in Tanzania. Green and Sustainable Chemistry, 5: 154-163. http://dx.doi.org/10.4236/gsc.2015.54019

[13] Yusuf A., Mamza A., Ahmed A. & Agunwa U. (2015). Extraction and characterization of castor seed oil from wild ricinus communis linn. International Journal of Science, Environment and Technology. 4:1392-1404. http://ljs.academicdirect.org/A08/43_52.pdf

[14] Adam O., Khalid A., Abdi A., Yaagoub I., Babiker A. & Nour A. (2020). Proximate composition, physicochemical properties and antioxidant activity of flaxseed. Annual Research & Review in Biology. 34: 1-10. https://doi.org/10.9734/arrb%2F2019%2Fv34i230148

[15] Kyari M. (2008). Extraction and Characterization of Seed Oils. International Agrophysics, 22: 139-142. http://www.international-agrophysics.org

[16] Akpan U., Jimoh A., & Mohammed D. (2006). Extraction, Characterization and Modification of Castor Seed Oil. Leonardo Journal of Sciences. 8: 43-5. old.international-agrophysics.org.

[17] Orijajogun J., & Ayegba C. (2017). Physicochemical Properties and Fatty Acid Composition of Castor Bean Ricinus communis L. Seed Oil. American Journal of Applied and Industrial Chemistry. 3(1): 1-4. https://doi.org/10.11648/j.ejb.20170504.11

[18] Yeboah A, Ying S, Lu J, Xie Y, Amoanimaa-Dede H, Boateng KGA, et al (2020). Castor oil (Ricinus communis): a review on the chemical composition and physicochemical properties. Food Science and Technology. 41: 399-413. https://doi.org/10.1590/fst.19620

[19] Jumat S. & Dina A. (2017). Fatty Acid Composition and Physicochemical Properties of Malaysian Castor Bean Ricinus communis L. Seed Oil. Sains Malaysiana. 39: 761–764. http://www.ukm.my/jsm/english_journals/vol39num5_2010/contentsVol39num5_2010.html

[20] Kochhar S. (1998). Economic Botany in the Tropics, 2nd ed., Macmillan India Ltd., pp. 171. 313191 (wur.nl). https://doi.org/10.1038/144563a0

[21] Warra A. (2015). Physico-chemical and GC/MS Analysis of Wild Castor (Ricinus communis L.) Seed Oil. Applied Science Reports. 9(3): 123-128. https://doi.org/10.15192/PSCP.ASR.2015.9.3.123128

[22] McKeon, T. A. (2016). Castor (Ricinus communis L.). Industrial oil crops, Elsevier. 75-112. https://doi.org/10.1016/B978-1-893997-98-1.00004-X