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Physical and Chemical Properties of Selected Sample of Castor Oil, *Ricinus communis* L.

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Abstract

The seeds of the castor oil plant (*Ricinus communis* L.) are commonly used for obtaining castor oil that has various use in several industries, such as chemical, pharmaceutical, agricultural, and other industrial sectors. It is utilised for the production of care products, such as soaps and shampoo, lubricants, plastics, *etc*. Previous research has shown the benefits of using castor oil as a biodiesel and a renewable energy source. The aim of this work was to determine the physical and chemical properties of castor oil. Physical and chemical properties of selected sample of castor oil were analysed according to standard analytical methods for fats and oils. The results of analysis showed that castor oil, due to its physical and chemical properties, has a potential and relevance in cosmetic and pharmaceutical application. It can be used as raw material in different formulations, as well as for production of valuable co-products, such as glycerol.

Keywords

Castor oil, physical parameters, chemical parameters

1 Introduction

The castor oil plant (*Ricinus communis* L.) is one of the most used cultivated crops in industry, particularly as a valuable and renewable source in the chemical industry (Fig. 1).[1,2] Castor oil is obtained from the seeds of the castor oil plant by cold or hot pressing, and it is insoluble and resistant to water (Fig. 2).[3]

Fig. 1 – Leaves and flowers of castor oil plant (*Ricinus communis* L.)[4]
Slika 1 – Lišće i cvijet biljke ricinusa (*Ricinus communis* L.)[4]

The importance of castor oil as a valuable raw material in various branches of industry, especially in the chemical industry, is due to the presence of the hydroxyl group in the structure of fatty acid in its composition. This functional group and its location in the structure of castor oil allows for a variety of chemical reactions in industrial applications, and thus its use as a starting material for the production of soaps and other care products, lubricants, hydraulic and brake fluids, coatings, plastics, and polishes.

The major constituents of the oil are ricinol, stearic, dihydroxy stearic, oleic and linoleic acids, triacylglycerols, as shown in Fig. 3.[3,6] It is a yellow liquid and has a characteristic taste and odour, with high density, depending on the content of lipids. It includes a mixture of triglycerides, mainly ricinoleate (about 90 %), while oleate and linoleate are present in various percentages in the oil composition.

Castor oil contains a unique and rare hydroxy fatty acid, ricinolenic acid (Fig. 4), which is structurally cis-12-hydroxy-octadeca-9-ene acid (hydroxyl fatty acid with C18 atoms and one double bond). Due to castor acid, this oil

Fig. 2 – Castor oil[5]
Slika 2 – Ricinusovo ulje[5]

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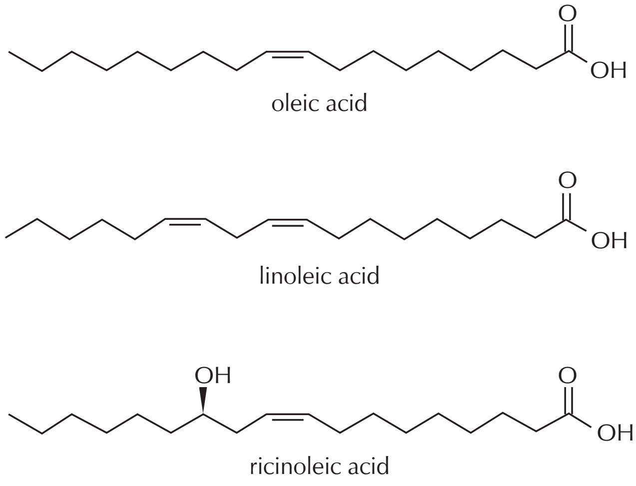

Fig. 3 – Main structural constituents of castor oil
Slika 3 – Glavni strukturni konstituenti ricinusova ulja

has different physicochemical characteristics and fatty acid profile compared to other natural oils, and makes it applicable for various purposes, from medical and pharmaceutical to industrial applications. Castor oil contains as much as 90 % castor acid, and it has been proven very effective against fungi, moulds, viruses, parasites, and bacteria.[7]

Castor oil has a very constant viscosity and does not freeze even at very low temperatures, which makes it an ideal lubricating oil in various branches of industry.[8] Although ricin is one of the strongest poisons in the world, castor oil is not toxic but a valuable natural remedy used for the overall well-being of the body.[9] Castor oil has long been used in: sciatica, baldness, arthritis, poor circulation, constipation, breast tumours, fibroids and cysts, warts, bronchitis and colds, autoimmune disorders, Parkinson's disease, epilepsy, multiple sclerosis, and cerebral palsy. It is especially important to use this oil in people who have undergone X-ray and radiological testing. In addition, for medical purposes, castor oil is added to hair restoration products, and to the production of special soaps, while alcoholic castor oil extracts are used for their anti-inflammatory and antimicrobial properties (especially against pathogenic bacteria).[10,11]

Refining and cracking after steam distillation yields C7 and C11 products that have been used in perfume production and polyamide material (Rilsan), the salts of which have antifungal properties. The content of triacylglycerol and other fatty acids (palmitic, stearic, and linoleic) makes castor oil useful in the textile industry (final processing of cotton and linen materials), the dyes and inks industry, and especially for dyeing in the textile industry as Turkish red oil (sulfonated castor oil).[12]

The aim of this work was to analyse the physical and chemical properties of a selected sample of *Ricini communis* L. (castor) seed oil (*Ricini oleum*), purchased from a pharmacy in Sarajevo, and to show its potential and significance for use in the chemical, cosmetic, pharmaceutical, and other industry sectors.

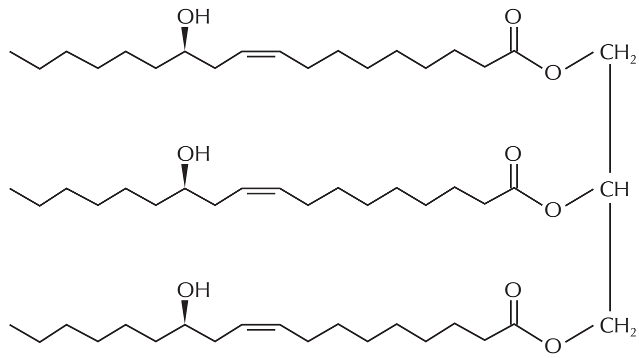

Fig. 4 – Structure of triricinoleate molecule
Slika 4 – Struktura molekule triricinoleata

2 Materials and methods

2.1 Chemicals

All chemicals and reagents used in this study were of high analytical grade and purchased from Sigma Aldrich (Germany). The solvents and solutions used for this analysis included: ethanol, methanol, ether, phenolphthalein, starch. Sulphuric acid (97.00–99.00 %), hydrochloric acid (35.00 %), potassium hydroxide, sodium thiosulfate, potassium iodine, iodine, standard buffer solutions (pH 4 and 7) were purchased from Merck (Germany). Milli-Q water was used to prepare the solutions throughout the experiments.

2.2 Samples

Used was one sample of castor oil (*Ricini oleum*, Ph. Eur) produced by MaxiVita (Gradačac, B&H), purchased from a pharmacy in Sarajevo, Bosnia and Herzegovina, and stored at 2–4 °C until analysis.

The physical and chemical properties of the castor oil were analysed applying protocols for standard reference methods for the determination of fats and oils: specific gravity (AOCS Official Method To 16-64), refractive index (AOCS Official Method Cc 7-25), viscosity (AOCS Official Method Tq 1a-64), Acidic value (AOCS Official Method Cd 3d-63), iodine value (AOCS Recommended Practice Cd 16-87), saponification value (AOCS Official Method Cd 3-25), and free fatty acids (Official Method Ca 5a-40).

The following instruments and equipment were used for the analysis: pH-meter (Mettler Toledo EL20-Kit Benchtop Education pH Meter, Zagreb, Croatia), Ostwald viscometer (Semikem, Sarajevo, Bosna and Hercegovina), Abbe refractometer (Abbe laboratory refractometer 98.490 SUPERLAB®, Novi Beograd, Serbia), and Analytical balance (KERN ABS-N analytical balance, Stuttgart-Balingen, Germany).

2.3 Determination of physical parameters

For the selected sample of castor oil, the physical properties such as specific gravity, viscosity, refractive index, and pH were analysed.[13] The experimental results were processed by analysis of variance (ANOVA) using a full factorial experimental design. This study showed that the optimal conditions for PVC biodegradation are low values of shaking (120 rpm), a high OD (1.0), and a medium pH (5).

Determination of specific gravity

A clean and dry pycnometer was weighed (m_0) and filled with the oil, and again weighed (m_1). A second pycnometer filled with distilled water was then weighed (m_2). Specific gravity (ρ) was calculated using Eq. (1):

$$\rho = \frac{m_1 - m_2}{m_2 - m_0} \qquad (1)$$

where m_0 is weight of an empty pycnometer, m_1 is weight of a pycnometer filled with oil, and m_2 is weight of a pycnometer filled with distilled water.

Determination of viscosity

A clean and dry Ostwald viscometer was filled with the sample of castor oil, and placed into a bath at constant temperature of 20 °C. Three measurements were done using water as a standard.

Determination of refractive index

Abbe's refractometer was used to determine the refractive index of castor oil. A few drops of the oil sample were transferred into the glass slide of the refractometer, which was calibrated with distilled water, and the refractive index at room temperature of 25 °C was measured. Three measurements of castor oil sample were recorded.

Determination of pH

The pH meter with a calibrated combined electrode was used for measuring pH value of castor oil sample at 25 °C. Previously, the oil sample was prepared by dissolving 2 g of the castor oil in hot distilled water and cooled to room temperature. Three measurements of the oil sample were recorded.

2.3 Determination of chemical parameters

The chemical characteristics of castor oil, such as acidic value, iodine value, saponification value, and peroxide value, were determined using standard titrimetric methods.

Determination of acidic value

The acidic value of castor oil sample was determined by titration with standard solution of KOH. Briefly, 5.0 g of the castor oil sample was placed into a dried volumetric flask, followed by the addition of 100 ml of absolute ethanol and 2–3 drops of phenolphthalein as indicator, and heated in a water bath for 5 min. The hot solution was shaken vigorously and titrated with 0.1 mol l^{-1} KOH until it turned a pink colour. Three measurements were taken. The acidic value (A_V) of the oil sample was calculated by Eq. (2):

$$A_V = \frac{56.1 \cdot V \cdot M}{m} \qquad (2)$$

where, V is volume of KOH used, M is molarity of KOH, and m is mass of oil sample.

Determination of iodine value

The acidic value of castor oil sample was determined by titration with standard solution of $Na_2S_2O_3$. A mixture of 15 ml of chloroform and 25 ml of iodine solution was added to a 1.38 g oil sample in a measuring flask. The flask was closed and the solution shaken manually for a few minutes. into this solution was added 15 ml of 10 % potassium iodide and 100 ml of redistilled water. The mixture was titrated with 0.1 M sodium thiosulfate solution until it turned yellow, added were 2–3 drops of starch solution as an indicator, which turned the solution into blue, and titration continued until the blue colour disappeared. Three measurements of the sample were taken, and the iodine value (I_V) for the castor oil sample was calculated by Eq. (3).

$$I_V = \frac{12.69 \cdot c \cdot \left(V_1 - V_2\right)}{m} \qquad (3)$$

where, c is concentration of $Na_2S_2O_3$, V_1 is volume of $Na_2S_2O_3$ used for the blank, V_2 is volume of $Na_2S_2O_3$ used for castor oil sample, and m is mass of castor oil sample of.

Determination of saponification value

The saponification value of castor oil sample was determined as follows: into a volumetric flask, 1 g sample of the castor oil was weighed, and 25 ml of 0.5 M ethanolic potassium hydroxide was added. The flask was then fitted to a reflux condenser in a water bath for 1 h, after which 3–4 drops of phenolphthalein as an indicator were added to the hot solution, and titrated with 0.5 mol l^{-1} HCl. The same procedure was used for blank sample, and three measurements of oil sample were taken. The saponification value (S_V) was calculated using Eq. (4).

$$S_V = \frac{56.1 \cdot M \cdot \left(B - S\right)}{m} \qquad (4)$$

where, B is the volume of the solution used for blank sample, S is the volume of the solution used for analysis of oil sample, M is molarity of the HCl used, and m is mass of castor oil sample.

3 Results and discussion

The physicochemical properties of castor oil, such as specific gravity, refractive index, acidic value, iodine value, saponification value, free fatty acids, and pH value from literature and experimental data are presented in Tables 1 and 2, respectively. Refractive index (at 25 °C), and specific gravity (at 20 °C) was found to be 1.4770, and 0.9601 g cm^{-3} while literature data for the refractive index and specific gravity were 1.4770, and 0.9610 g cm^{-3} (Table 1). The chemical parameters, such as A_V, I_V, and S_V of analysed castor oil sample were determined at 0.53 mg KOH/50 g, 84.49 mg I_2/100 g, and 190.0 mg KOH/100 g, respectively. The quality of oil depends on the presence of free fatty acids (FFA). Generally, these values are calculated as percentage of oleic acid. In the current work, the value of FFA in castor oil sample was 0.37 % (Table 2). These measured values are comparable to literature data for castor oil (Table 1).

Table 1 – Physicochemical properties of castor oil (literature data)[8]
Tablica 1 – Fizičko-kemijska svojstva ricinusova ulja (literaturni podatci)[8]

Physicochemical properties	Castor oil
specific gravity, 20_{25}	0.9610 g cm^{-3}
refractive index, n_D	1.4770
viscosity, η	630–880 mPa s
acidic value, mg KOH/50 g oil	0.4–4.0
iodine value, mg I_2/100 g oil	85.5
saponification value, mg KOH/100 g oil	180.3
free fatty acids, %	0.3–0.7
pH	6.00–7.00
melting point	−18.0 °C
boiling point	>300 °C

Table 2 – Physicochemical properties of castor oil (experimental)
Tablica 2 – Fizičko-kemijska svojstva ricinusova ulja (eksperimentalna)

Physicochemical properties	Castor oil
specific gravity, 20_{25}	0.9601 g cm^{-3}
refractive index, n_D	1.4770
viscosity, η	630–880 mPa s
acidic value, mg KOH/50 g	0.53
iodine value, mg I_2/100 g oil	84.49
saponification value, mg KOH/100 g oil	190.0
free fatty acid, %	0.37
pH	6.00

The specific gravity of the castor oil analysed was the same as the value for this oil according to European Pharmacopoeia and other literature data.[8] The refractive index corresponds to the values in other studies, and shows the level of saturation and the content of FFA, which is a parameter for oil flammability. The pH (6.00), which is similar to the works of other authors[3,12,14] and with the found percentage of FFA (0.37 %), makes this oil useful and applicable for soap production and industrial use.[7,14]

The acidic value represents the concentration of free fatty acids in the oil and is a good indicator of oil quality. In this work, the acidic value was found at 0.53, which is in the range of values from literature (0.4–4.0 mg KOH/g oil). Vegetable oil with higher free fatty acid content has poor quality; therefore, low acidic value is a good indicator of vegetable oil quality and could be valuable data for refining process.[14]

The iodine value shows the unsaturation level of fats or oils in the oil sample. A higher iodine value means a higher level of unsaturation and lower value indicates a low unsaturation level of oil, and therefore, low content of unsaturated fatty acids. In literature, for the castor oil the range of iodine value is 83–93 mg I_2/100 g oil.[15] According to this, castor oil has been regarded as a non-drying oil since the value is less than 100, which makes it useful for hydraulic brake fluids and lubricants. The iodine value of 85.49 mg I_2/100 g oil in this work indicates that this castor oil sample is a non-drying oil, and can be used as a good lubricant, particularly in the cosmetic and pharmaceutical industries for care products. In addition, since the iodine value is < 100, the analysed castor oil is suitable for soap production.[16]

The saponification value of vegetable oil as a chemical property is a very important characteristic of oil. Low saponification value of oil shows high molecular weight of the triglyceride, while high saponification value indicates low molecular weight of the triglyceride in the oil.[14,17] In addition, low saponification value in oil samples has demonstrated that such oils are unsuitable for industrial use, while the high saponification value confirms its useful application for the manufacture of soaps and other cosmetic care products. The saponification value of selected castor oil sample in this work was 190.0 mg KOH/g oil, which is higher compared to results of other studies, confirming the analysed castor oil a useful raw material in the soap industry and cosmetics care products.[18–21]

The quality of the castor oil, as well as its physicochemical characteristics and fatty acid composition and content are influenced by many factors, mostly by the planting area, grain immaturity, and poor storage conditions. High values of specific gravity and viscosity of castor oil relative to other natural oils are conditioned by the structure and composition of the fatty acids present. In addition, the profile and composition of fatty acids in castor oil are strongly influenced by climatic (temperature, humidity, soil composition, *etc.*) and geographical conditions.[22,23]

4 Conclusion

In this work, the physicochemical properties of selected castor oil sample were analysed. The obtained results of analysis indicated that castor oil, due to its physicochemical properties, has great potential and significance for application in the pharmaceutical and cosmetic industry, textile industry, chemical and other industrial branches. A limitation of this work is the number of analysed samples of castor oil, and for verification of these results, a larger number of castor oil samples should be analysed.

List of abbreviations and symbols
Popis kratica i simbola

A_V – acidic value
– kiselinski broj

FFA – free fatty acid
– slobodna masna kiselina

I_V – iodine value
– jodni broj

ρ – specific gravity
– specifična težina

S_V – saponification value
– saponifikacijski broj

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SAŽETAK

Fizička i kemijska svojstva odabranog uzorka ulja ricinusa, *Ricinus communis* L.

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Sjemenke biljke ricinusa (*Ricinus communis* L.) obično se upotrebljavaju za dobivanje ricinusova ulja, koje ima različitu primjenu u nekoliko industrija, kao što su kemijska, farmaceutska, poljoprivredna i druge industrijske grane. Upotrebljava se za proizvodnju sredstava za njegu, kao što su sapuni i šamponi, lubrikanti, plastika itd. Prethodna istraživanja pokazala su prednosti uporabe ricinusova ulja kao biodizela i obnovljivog izvora energije. Cilj ovog rada bio je odrediti fizička i kemijska svojstva ricinusova ulja. Fizička i kemijska svojstva odabranog uzorka ricinusova ulja analizirana su prema standardnim analitičkim metodama za masti i ulja. Rezultati analize pokazali su da ricinusovo ulje zbog svojih fizičkih i kemijskih svojstava ima potencijal i značaj u kozmetičkoj i farmaceutskoj primjeni. Može se upotrebljavati kao sirovina u različitim formulacijama, kao i za proizvodnju vrijednih nusproizvoda, poput glicerola.

Ključne riječi
Ricinusovo ulje, fizička svojstva, kemijska svojstva

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