

Comparative Study of Physico-Chemical Properties of Coconut Oil (*Cocos nucifera L.*) Obtained by Industrial and Artisanal Processes

Jakeline Santos Martins¹, Jose Carlos Oliveira Santos^{1*} and Marta Maria da Conceicao²

¹Academic Department of Biology and Chemistry, CES, Universidade Federal de Campina Grande, UFCG, Cuité, Paraíba, 58175-000, Brazil

²Center for Technology and Regional Development, CTDR, IDEP, Universidade Federal da Paraíba, UFPB, Joao Pessoa, Paraíba, 58051-900, Brazil

***Corresponding author:** Jose Carlos Oliveira Santos, Academic Department of Biology and Chemistry, CES, Universidade Federal de Campina Grande, UFCG, Cuite, Paraíba, 58175-000, Brazil, Tel: 5583998912607; E-Mail: zecarlosufcg@gmail.com

Received date: September 30, 2020; **Accepted date:** October 15, 2020; **Published date:** October 23, 2020

Abstract

Coconut oil (*Cocos nucifera L.*), widely used by the food and pharmaceutical industry, has required analytical methods capable of evaluating processing and storage conditions. In this work, the chemical composition and physicochemical properties of the extra virgin coconut oil produced by the Brazilian industry and the coconut oil obtained in a handmade way were compared. The results confirm the high content of saturated fatty acids in coconut oil, mainly due to the high content of lauric acid (approximately 2% for extra virgin oil and 3% for oil obtained by hand), responsible for increasing the oxidation stability, besides changing the oil melting profile, contributing to the increase of the use of the fat of this oil in specific products of the pharmaceutical and food industries. It can be estimated that in most cases the results obtained for samples of industrial and artisanal coconut oil were higher than the standards established by National Agency of Sanitary Surveillance. However, the analyzes made of coconut oil were extremely important to be able to refer to this oil, as its studies are still scarce and controversial in the literature. Considering that coconut oil is widely used in the media, the comparative analysis of the chemical composition and the physico-chemical characteristics of the oils studied can contribute significantly to provide clarification on the difference Among the oils, when obtained through the industrial and artisanal processes, aiming to make people aware of obtaining a quality product.

Keywords: Coconut oil; Handicraft production; Chemical composition; Food

Introduction

Vegetable oils are extracted from different oil plants and used mainly as a source of food and in the production of cosmetics, lubricants, paints, pharmaceuticals, biodiesel, among others [1]. Oils and fats are recognized as an essential nutrient for the animal diet, constituting the most concentrated source of energy of the food [2]. Lipids, biomolecules that have high solubility in organic solvents and low solubility in water, are essential supplements of fatty acids, precursors of important hormones such as

Citation: Martins JS, Santos JCO, da Conceicao MM. Comparative Study of Physico-Chemical Properties of Coconut Oil (*Cocos nucifera L.*) Obtained by Industrial and Artisanal Processes. *Biotechnol Ind J.* 2020;16(3):210.

©2020 Trade Science Inc.

prostaglandins. Fatty acids are considered the building blocks of lipids and constitute about 90% of fats in foods [3].

The coconut tree (*Cocos Nucifera L.*), originating in Southeast Asia, was introduced in Brazil in 1553, where it is naturalized in long areas of the northeastern coast, providing abundant raw material for both regional agroindustry's and food use. Coconut oil, obtained from the pulp of mature fresh coconut (*Cocos nucifera L.* species), is composed of saturated fatty acids (more than 80%) and unsaturated fatty acids. The saturated fatty acids present in coconut oil are: caproic, caprylic, capric, lauric, myristic, palmitic and stearic; and the unsaturated ones are: oleic and linoleic. Coconut oil is rich in lauric acid, with concentration above 40%. The lauric fats, in the case of coconut oil, are resistant to non-enzymatic oxidation and, unlike other oils and fats have a low and well defined melting temperature (24.4°C-25.6°C). Lauric fats are widely used in the cosmetic and food industry. Due to their physical properties and resistance to oxidation, they are widely used in the preparation of special fats for confectionery, ice cream, margarine and cocoa butter substitutes [4,5].

In recent years, some studies have shown that coconut fat is able to generate heat and burn calories, favoring weight loss. Coconut oil has also been indicated to lower triglycerides and bad cholesterol (LDL), increase good cholesterol (HDL) and have anti-inflammatory action [6]. In addition, fat from coconut oil leads to normalization of lipids, protects the liver from the effects of alcohol and increases the immune response against various microorganisms, and is also beneficial in combating risk factors for cardiovascular diseases [7]. When subjected to high temperatures, the virgin coconut oil does not lose its nutritional characteristics, being considered stable oil. It is also considered the healthiest to cook, not presenting trans-fat generated by the hydrogenation process, which is present in all other oils of vegetable origin, such as soy, canola, corn and even olive oil, which is considered the oil more saturated fats [8].

Vegetable oils have several applications in industrial processes and because of these potentialities, have constantly increased their demand for production [9-13]. This work aims to evaluate the chemical and physicochemical properties of samples of industrial and artisanal coconut oil, in a comparative way.

Materials and Methods

Materials

Samples of 200 grams of coconut oils were analyzed in duplicate, being an extra-virgin sample, contained in appropriate containers, produced by Brazilian industry and available on the market, and another sample purchased at the fair-free of the city of Cuite, Paraiba, Brazil, produced by means of artisanal, to compare the effects of the production processes on the composition in fatty acids and physical and chemical characteristics of the oils. The analyzes were done in laboratory environment and at room temperature.

Chemical characterization

Analysis of fatty acid composition was performed by gas chromatography of the methyl esters, according to the method Ce 1-91 of AOCS (1993) [14]. Determination of fatty acid composition by gas chromatography was performed under the following conditions:

- Chromatograph: HP 5890 series II, with flame ionization detector
- FFAP fused silica capillary column: 25 × 0.2 mm × 0.33 µm i.d
- Drag gas: Analytical hydrogen 5.0
- Drag gas flow: 1.00 mL/min
- Column temperature: 120°C to 210°C, with programming of 2°C/min
- Injector temperature: 250°C
- Detector temperature: 280°C
- Start time: 1 min

- End time: 32 min
- Head pressure: 65 KPa
- Split rate: 1/100

The identification of the fatty acids was performed by comparing the retention times of the test samples with the retention time of methyl ester chromatographic standards. The quantification was done by converting the percentages of areas of the peaks in percentage of mass.

Physical-chemical characterization

The physicochemical properties were determined using specific methods mentioned in the literature [11,12], being analyzed the pH, solubility, acidity index, saponification index, iodine index, peroxide content, moisture content, ash content and free fatty acid content.

The pH of the coconut oil samples was measured at room temperature in a HANNA pH-meter pH/mv.

The solubility of the coconut oil samples was analyzed in aqueous medium, alcohol (ethanol) and ethyl ether at 25°C. The samples were placed in 50 mL beaker, where the respective reagents were added to allow the dissolution of the samples to be observed.

The determination of moisture was performed by gravimetric method. The experimental procedure is described below: About 25 g of coarse sand were weighed and placed in a flat bottom porcelain capsule containing a glass rod. This set of materials was oven dried at 105°C for 1 hour and then cooled in a desiccator until it reached room temperature and could be weighed. Immediately after weighing, 10 mL of the coconut oil of each sample to be analyzed was placed on the dry sand and weighed again to obtain the mass of the capsule containing the moist sample. With the help of the glass rod, the oil sample was mixed with the sand. This material was oven dried at 105°C for 2 hours and then cooled in a desiccator until it reached room temperature and could be weighed to obtain the mass of the capsule containing the dried sample. Calculation of moisture was performed using the appropriate equation [15].

In the procedure for determining the acid number, in a previously tared 250 mL erlenmeyer flask, 2.01 g of coconut oil was added. Then 16.6 mL of ethyl ether and 8.3 mL of ethyl alcohol (2+1) were added to the mixture and stirred until complete dissolution of the sample. Then 2 drops of phenolphthalein and 1 drop of potassium hydroxide (KOH) were added and titrated with pre-standard solution 0.1 mol/L KOH until a slightly pinkish coloration appeared. To calculate the acid value, expressing the result in mg KOH/g coconut oil, the specific equation was used [15].

The saponification index was determined by placing 2 g of coconut oil in a pre-tared 250 mL flat bottom flask. Subsequently, 25 mL of potassium hydroxide (KOH) alcoholic solution was added and stirred for complete dissolution of the sample. In another 250 mL flat bottom flask was placed 25 mL of KOH to make the blank. The flasks were then fitted to the reflux condensers and heated in a water bath for 30 min. Every 5 minutes the solution was stirred so that there was a better dissolution of the sample. When removed from the water bath, it was titrated with 1 mol/L hydrochloric acid (HCl) until phenolphthalein bleaching. To calculate the saponification index, expressing the result in mg of KOH/g of oil, the equation described in the literature [15].

In the determination of the iodine value, in a previously tared 250 mL erlenmeyer, 0.30 mL of the coconut oil was added and weighed. Then, 15 mL of chloroform was added and stirred until complete dissolution of the sample. Then 25 mL of the Rubl Reagent was added. The sample was left in a dark place for 4 hours. Then 15 mL of potassium iodide (10% KI) and 100 mL of distilled water were added. Thereafter, the excess of iodine was titrated with sodium thiosulphate in the presence of starch. The spent volume was recorded and the iodine value of the coconut oil was calculated expressing the result in g iodine/100 g of the oil. He made a blank proof in parallel. To determine the iodine value of coconut oil, the appropriate equation [15]. The appearance of the coconut oils was analyzed visually, in order to observe the presence of impurities.

The ash content was determined by placing a porcelain dish in a QUIMIS muffle at a temperature of 600°C for 20 minutes and then cooling. When it was reached at room temperature, 2.0 g of coconut oil was added and weighed. Immediately after the assembly was placed in the oven at 600°C for 4 hours. After the sample cooled, it was weighed again. For the determination of ash of the oil of the coconut oils, the appropriate equation was used [15].

To obtain the density, in a pre-weighed 25 mL beaker, 10 mL of oil was placed into the pre-weighed beaker and weighed on a scale DIGMED, model DG-2000, and the weight recorded. For the determination of the densities of the coconut oil samples, the specific equation [15].

The free fatty acid content, expressed as a percentage of lauric acid, was determined by adding 2.01 g of coconut oil in a pre-weighed 250 mL conical flask. Thereafter, the mixture of 16.6 mL of ether and 8.3 mL of alcohol (2+1) was added and stirred until the sample was dissolved. Then two drops of phenolphthalein and one drop of KOH were added and titrated with potassium hydroxide (0.1 mol/L KOH, standard) until a clear pinkish color appeared. To calculate the lauric acid index an appropriate equation was used [15].

In the determination of the peroxide index, in a previously tared 250 mL erlenmeyer, 1 g of the coconut oil sample was placed. Thereafter, 20 mL of 3:2 acetic acid-chloroform solution was added, stirring until the sample was completely dissolved. Then, 0.5 mL of KI was added and three shakes were added in 1 min at rest at the end of the procedure, immediately, 10 mL of distilled water was placed. The $\text{Na}_2\text{S}_2\text{O}_3$ solution is then slowly titrated under constant magnetic stirring until the yellow color disappears almost completely, and 2 mL of the starch solution is added to continue the titration with stirring until the blue color disappears, releasing all iodine from the solvent layer. To determine the peroxide index of the coconut oil samples, the equation described by Martins and Santos [15].

Results and Discussion

Coconut oil is considered an exception when compared to other vegetable oils, because although it is highly saturated, it is liquid due to the predominance of medium chain fatty acids, which correspond to 70%-80% of its composition. The fact that coconut oil has a higher amount of medium chain fatty acids, unlike other saturated fats, causes it to have a different metabolic behavior due to its structural characteristics. The fatty acid composition of the analyzed oils is listed in **TABLE 1**.

TABLE 1. Composition in fatty acids (% 100 g) of coconut oil.

Fatty acids	Fatty acid content (%)	
	Extra virgin coconut oil obtained by industrial means	Coconut oil obtained by artisanal means
Caproic acid	0.38	0.30
Caprylic acid	5.56	6.64
Capric acid	4.99	6.00
Lauric acid	45.78	47.13
Myristic acid	18.56	18.60
Palmitic acid	8.85	8.70
Stearic acid	3.39	2.59

Oleic acid	5.65	7.70
Linoleic acid	0.94	1.34

The results confirm the high content of saturated fatty acids of coconut oil, mainly due to the high content of lauric acid, which together with the hydrogenation can increase the oxidative stability of the product, besides changing the melting point, increasing the range the use of these fats in specific products. Vegetable oils when subjected to hydrogenation to achieve the melting and stability characteristics required to make ice creams are subject to the appearance of new types of compounds, among them the trans isomers [16]. The formation of trans isomers during the partial hydrogenation of vegetable oils is proportional to the formation of drastic processing conditions, such as high temperatures. In nutritional terms the trans isomers are digested, absorbed and incorporated by the body in a similar way to cis isomers, but they do not present activity as essential fatty acids. There are some aspects still not fully elucidated regarding the influence of trans isomers on some types of cancer, atherosclerosis and other health problems [17].

In establishing the quality parameters for the acceptability of vegetable oils, it is important that the values for the acid number are the lowest, since high values are indicative of pronounced changes, compromising their ability to use them, whether for food or Fuels. The physicochemical parameters evaluated for the samples of coconut oils analyzed in this work are listed in **TABLE 2**.

TABLE 2. Physical-chemical parameters of coconut oil samples.

Analysis	Extra virgin coconut oil obtained by industrial means	Coconut oil obtained by artisanal means	Standard for coconut oil (Brazil, 1999)
Aspect	Clear, no impurities	Clear, no impurities	Clear, no impurities
Ashes (%)	0.005	0.005	-
Density (g/mL)	0.897	0.896	0.903-0.924
Acidity level (mg KOH/g oil)	0.558	0.837	0.3<(gross); 0.5<(refined)
Lauric acid (%)	1.990	2.985	0.5%<
Iodine Index	15	21	14-23
Saponification Index (mg KOH/g oil)	222	233	247-255
Moisture (% H ₂ O)	0.263	0.382	-
pH	3.33	3.50	-
Peroxide index	0.959	2.158	-

The monitoring of the acidity of vegetable oils is also used as an auxiliary method during the stages of processing, storage and quality control [12]. The acidity index reveals the state of conservation of the oil, expressed as the number of milligrams of potassium hydroxide needed to neutralize the free acids of one gram of the sample. The high acidity index indicates, therefore, that the oil is suffering breaks in its chain, releasing its main constituents, the free fatty acids. The calculation of this index is extremely important in assessing the state of deterioration of the oil that is supplied for consumption. By means of this method, one can

determine if the oil underwent hydrolytic or oxidative rancification.

The mean values of acidity determined in the samples were below the maximum value established for crude oils (4.0 mg KOH/g oil). These results demonstrate that lipid hydrolysis and oxidation did not occur during the production and storage of the oil and that probably the ambient temperature and the storage conditions in which the samples were present did not affect the constituent fatty acids very much, being evidenced by the acidity of the conform to the standards of conformity. The acid value of the coconut oil sample, however, was higher in relation to the industrial coconut oil sample, as shown in **TABLE 2**. The acidity index can usually reveal incorrect forms of fruit harvest, improper ripening and storage, and unsatisfactory extraction processes. In addition, fat decomposition by the enzyme lipase is accelerated by light and heat, forming free fatty acids that increase acidity and cause unpleasant taste and odor [18]. Therefore, the highest acidity value in a sample may be indicative of early development of hydrolytic reactions. In addition, the storage of the oil, made in plastic packaging without adequate protection against the passage of light, contributes to the reduction of its stability, since the sample of coconut oil extracted by hand may have remained during the storage period, more exposed to light and, therefore, have undergone greater alteration in the fatty acids content in relation to the other sample. Considering the above, it can be observed that, in general, the acidity indexes of coconut oil presented positive results, indicating a good initial state of conservation, and that, despite the adverse storage conditions; these were not sufficiently aggressive for the deterioration of the oils according to the limits of acceptability stated in the legislation.

The iodine value is a parameter used to predict the presence of double bonds in a fatty acid ester. The higher the value found for this index, the greater the degree of unsaturation, serving as indicative of tendency to oxidation of vegetable oils. The values described in the literature for the iodine index are generally presented as a value range, rather than a fixed number, because the degree of unsaturation may vary according to aspects related to the seasonality of the oilseed or depending on different types of oil processing.

The determination of the peroxide index in vegetable oils will serve as an estimate of the degree of degradability of the raw material. The presence of peroxides is not desirable in oils and fats, since it presupposes degradation processes. Even so, ANVISA (Brazilian National Health Surveillance Agency) resolution number 482/1999 [19] establishes limit values for some edible oils, and those considered to be good for consumption are those with a maximum value of 10 mEq/kg of oil or fat, for example oils peanut, linseed, palm oil, grape seed, among others. Changes in the sensory characteristics of vegetable oils are generally attributed to the presence of peroxides in the grease matter. They can also promote viscosity change, since they participate in the oxidation reactions, which end up forming compounds related to the increase of this parameter, for example the polymers [10].

Saponification index is the amount of base needed to saponify defined amount of oil and/or fat. It is expressed in the number of milligrams of potassium hydroxide needed to saponify one gram of the sample. The saponification index is an indication of the relative amount of high and low molecular weight fatty acids and does not serve to identify the oil, since many oils have very similar indices.

The values of the saponification indices obtained in the analyzed samples were below the limits determined by ANVISA (Brazil, 1999) [19] for coconut oil, as presented in **TABLE 2**. These results demonstrate the high proportion of low molecular weight fatty acids, but demonstrate the similarity between different oils analyzed in relation to the composition of fatty acids. The results can be explained considering the occurrence of a variation in the nature of its constituent fatty acids or even of possible adulterations with the addition of other types of vegetable oils with different saponification indices. The variations between the results of the saponification index can also be attributed to the particular characteristics of each oil, such as the form of cultivar and the region of cultivation. Another factor that must be taken into account is the difficulty in saponifying some samples, since they require more time for the process.

The ash content in food refers to inorganic residue, or fixed mineral residue (sodium, potassium, magnesium, calcium, iron, phosphorus, copper, chloride, aluminum, zinc, manganese and other mineral compounds) remaining from burning organic matter In high temperature (500°C-600°C) [9]. However, this is not always the case for the inorganic substance present in the sample, since some salts can be reduced or volatilized when heated at high temperatures [12]. **TABLE 2** shows the ash amount results in these oil samples. It can be concluded that the total insoluble matter obtained in the determinations of insoluble in the ether are of organic origin, since, after burning in muffle at 550°C, no ash content was obtained in the samples of coconut oil investigated. No values were found in the literature for the minimum limits for the determination of ash content in coconut oil.

During the process of refining edible oils, the concern is to eliminate the moisture acquired in some stages of the process to preserve the characteristics of the final product for a long period of time. The presence of moisture in the oils and the heat favor the activation of enzymes that rapidly hydrolyze the oil, producing a considerable increase in the free acidity generating an odor and unpleasant taste of rancid. Besides these conditions, they also lose valuable food components such as vitamins and antioxidants [12].

The iodine index is the measure of unsaturation in oils and fats and is used as a control for some processing. This index is based on the fact that iodine and other halogens are added in a double bond of the unsaturated fatty acid chain and expressed as the number of grams of iodine absorbed per 100 g of the sample.

Table 3 shows the solubility of coconut oil in different solvents. In aqueous medium, as expected, coconut oil samples did not mix with water, even with constant stirring, since oils and fats are nonpolar substances and water is polar. In an alcoholic medium coconut oil samples were not mixed with the alcohol. Samples of coconut oil showed total solubility in medium with ethyl ether (**TABLE 3**).

TABLE 3. Solubility of coconut oil samples.

Samples	Water	Ethyl alcohol	Ethyl ether
Extra virgin coconut oil obtained by industrial means	Insoluble	Insoluble	Soluble
Coconut oil obtained by artisanal means	Insoluble	Insoluble	Soluble

Conclusion

It can be estimated that in most cases the results obtained for samples of industrial and artisanal coconut oil were higher than the standards established by resolution number 482, of 09/23/1999, of the Brazilian National Agency of Sanitary Surveillance-ANVISA, where it can have negative effects on the quality of the oil, to the point of being unfit for human consumption.

The artisanal extraction method does not interfere in the physicochemical properties; since independent of the methodology adopted these parameters remain within the limits stipulated by the current legislation for cold pressed and unrefined oils. However, the analyzes made of coconut oil were extremely important to be able to refer to this oil, as its studies are still scarce and controversial in the literature. It is important to note that coconut oil is denominated as extra virgin because it has an acid value less than 0.5%. In addition, the saturated fat content of coconut oil is similar to that of human milk, which means that it is easily digested, generating energy quickly and beneficial effect on the immune system.

REFERENCES

1. Taghizadeh M, Solgi M, Shahrjerdi I. Various aspects of essential oils application for pathogens controlling in Strawberry in vitro culture. *Acad J Agric Res.* 2016;4(11):667-74.
2. Simopoulos AP. The importance of the ratio of omega-6/omega-3 essential fatty acids. *Biomed Pharmacother.* 2002;56(8):365-79.
3. Santos JC, Souza AG. Thermal stability of edible oils by thermal analysis. *J Food Tech.* 2007;5(1):79-81.
4. Marina AM, Man YC, Nazimah SA, et al. Chemical properties of virgin coconut oil. *J Amer Oil Chem Soc.* 2009;86(4):301-7.
5. Assunção mL, Ferreira HS, dos Santos AF, et al. Effects of dietary coconut oil on the biochemical and anthropometric profiles of women presenting abdominal obesity. *Lipids.* 2009;44(7):593-601.
6. Marina AM, Man YC, Amin I. Virgin coconut oil: emerging functional food oil. *Trends Food Sci Tech.* 2009;20(10):481-7.
7. Nevin KG, Rajamohan T. Beneficial effects of virgin coconut oil on lipid parameters and *in vitro* LDL oxidation. *Clin Biochem.* 2004;37(9):830-5.
8. Machado GC, Chaves JB, Antoniassi R. Fatty acid composition and physical and chemical characterization of hydrogenated babassu coconut oils. *Revista Ceres.* 2006;53(308):463-70.
9. Santos J, Santos I, Conceição M, et al. Thermoanalytical, kinetic and rheological parameters of commercial edible vegetable oils. *J Therm Anal Calorim.* 2004;75(2):419-28.
10. Santos JC, Dantas JP, Medeiros CA, et al. Thermal analysis in sustainable development: thermoanalytical study of faveleira seeds (*Cnidocolus quercifolius*). *J Therm Anal Calorim.* 2005;79(2):271-5.
11. Santos JCO, Souza AG, Prasad S. Influence of artificial antioxidants on thermal and oxidative stability of the rice bran oils using thermogravimetry and differential scanning calorimetry. *Chem Tech Ind J.* 2006;1(1):2-12.
12. Santos JC. Thermal characterization of the favelone oil (*Cnidocolus phyllacanthus*). *J Food Tech.* 2007;5(1):77-8.
13. Santos JC, Costa A, Araújo AL, et al. Chemistry and sustainable development: The use of brazilian regional plants in the context of chemical concepts. *Acad J Scient Res.* 2016;4(9):276-8.
14. AOCS (American Oil Chemists' Society) Official methods and recommended practices of the American Oil Chemists' Society. Champaign: AOCS. 1993.
15. Martins JS, Santos JCO. Comparative study of the properties of coconut oil obtained by industrial and artisanal processes. *Blucher Chem Proc.* 2015;3(1):515-26.
16. Nakpong P, Wootthikanokkhan S. High free fatty acid coconut oil as a potential feedstock for biodiesel production in Thailand. *Renew Energy.* 2010;35(8):1682-7.
17. Gebauer SK, Psota TL, Kris-Etherton PM. The diversity of health effects of individual trans fatty acid isomers. *Lipids.* 2007;42(9):787-99.
18. Lima L, Carvalho M, Santos J. Thermal and oxidative characterization of biodiesel derived from cotton oil. *Química no Brasil.* 2007;2(2):91-6.
19. Brazil. Ministry of Health: National Health Surveillance Agency (ANVISA). Resolution RDC No. 482 of September 23, 1999. Approves the Technical Regulation: Identity and Quality Fixation of Vegetable Oils and Fats. Brasília. 1999.