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Physical-Chemical Characterization and Nutritional Quality of Sesame Oil (Sesamum indicum L.).

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Abstract

The objective of this study was to analyze the physical and chemical characteristics of crude sesame oil (Sesamum indicum L.) and its nutritional quality. Determination of the fatty acid profile; of nutritional quality indexes (Atherogenicity Index (AI), Thrombogenicity Index (TI), the ratio between polyunsaturated fatty acids and saturated fatty acids (PUFA / SFA) and the Omega 6: omega 3 ratio); of the oil identity and quality standard (peroxide and acid indexes) and vitamin E were realized. The results were submitted to analysis of variance (ANOVA), with Tukey's post test to compare the averages between the groups. To compare only two groups, the t-test was used. The confidence interval was 95%. The Graph Pad Prism 5 software was used. The results of the study showed that the fatty acid profile of crude sesame oil is in accordance with recommendations recommended by Anvisa, being considered an important source of omega-6 and omega-9. Regarding the nutritional quality indices, the values of AI and TI were 0.14 and 0.07, respectively, considered low values that indicate that sesame oil can be considered beneficial to cardiovascular health. The acid and peroxide indexes are in accordance with the recommendations of Anvisa suggesting adequate standard of identity and product quality. The adequate peroxide content is indicative of the oxidative process, guaranteeing low oxidation, which can also be explained by the presence of vitamin E (28.34 mg / 100 ml). Concerning the clinical applicability, the consumption of sesame oil can be stimulated by the source of unsaturated fatty acids and vitamin E, besides presenting indexes of nutritional quality and adequate identity and quality standards. However, other studies need to be performed in relation to nutritional quality.

Keywords: Sesamum; Sesame oil; Fatty acids; Nutritional Quality; Identity and Quality Standards; Vitamin E

Introduction

The sesame seed belongs to the family *Pedaliaceae*, it is cultivated in tropical and subtropical countries, basically by small farmers having its origin in the African and Asian continents. Its main constituent is the oil that, depending on the type of cultivation and seed planting, can exceed 60% of its weight [2].

Sesame oil is defined, according to Resolution RDC No. 482, as "the edible oil obtained from *Sesamum indicum L.* seed by appropriate technological processes" and crude sesame oil is the "oil obtained by the extraction process" [3]. This process of extraction, according to Queiroga e Silva (2008), is carried out directly in the whole grains, by means of 4 steps: roasting of the grains, steam cooking, pressing and filtration [4].

It is known that sesame is an important source of oleic monounsaturated fatty acid, considered excellent oil [4, 5]. It is known that there is a great influence in relation to its ingestion and quantity of the fatty acids on the health, mainly, in relation to the cardiovascular diseases [6], which are considered the main cause of death in the world, around 37% [7]. Scientific evidence indicates that the increase in the consumption of unsaturated fatty acids present, for example, in vegetable oils is effective in preventing these diseases [8, 9]. The combination of the beneficial fatty acid profile and the rich nutritional composition of the sesame oil makes it possible to be considered a quality food with excellent functional properties.

The objective of this work was to analyze the physical and chemical characteristics of crude sesame oil and its nutritional quality.

Material and methods

Raw material: acquisition

Crude sesame oil (Sesamum indicum L.) was acquired from natural product houses. The analyzes were carried out at the Laboratory of Bromatology of the Institute of Nutrition (INU) of State University of Rio de Janeiro (UERJ) and at CBO Laboratory in Campinas, São Paulo.

Physicochemical analysis

Determination of the Fatty Acid Profile: The fatty acid profile was determined in triplicate by high resolution gas chromatography, according to the analytical methods of the associations of official analytical chemists [11]. Initially, the determination of ethereal extract was carried out by the Soxhlet method [12, 13], for further analysis of fatty.

Determination of nutritional quality indices: The nutritional quality of crude sesame oil was determined by fatty acid composition, taking into account the following indexes: atherogenicity index (AI) which considers saturated fatty acids as lauric, myristic as atherogenic and Unsaturated fatty acids as anti-atherogenic and palmitic; The Thrombogenicity Index (TI), which considers monounsaturated, polyunsaturated fatty acids as antithrombogenic and saturated fatty acids (myristic, palmitic and stearic) as thrombogenic [14]; the ratio between polyunsaturated fatty acids and saturated fatty acids (PUFA / SFA, according to London (1984) [15] and, also, the ratio of omega 6:omega

AI= [(C12:0) + (4 × C14:0) + (C16: 0) + (C16: 0)] / (PUFA n-6 + PUFA n-3 + MUFA), where C12: 0, C14: 0 and C16: 0, respectively, the saturated fatty acids lauric, myristic and palmitic; And PUFA n-6, PUFA n-3 and MUFA, respectively, omega-6 and omega-3 polyunsaturated fatty acids and monounsaturated fatty acids

IT = (C14:0 + C16:0 + C18:0) / [(0,5 × MUFA) + (0,5 × PUFA n-6) + (3 × PUFA n-3) + (PUFA n-3 / PUFA n-6)], where C14: 0, C16: 0 and C18: 0, respectively, myristic, palmitic and stearic acids; MUFA represents the sum of the concentrations of all monounsaturated fatty acids; PUFA n-6 represents the omega-6 polyunsaturated fatty acid and PUFA n-3 represents the omega-3 polyunsaturated fatty acid [14].

Determination of the oil identity and quality standard: To determine the nutritional quality of crude sesame oil, acid and peroxide indices were analyzed to determine the oil identity and quality standard.

The determination of the acid index consisted of weighing 2 g of the sample, in an analytical balance model AW 220, in triplicate, well homogeneous and completely liquid, in an Erlenmeyer flask of 125 mL. Then, 25 mL of neutral ether-alcohol (2: 1) solution and 2 drops of the phenolphthalein indicator were added. The last step was titration with 0.1M sodium hydroxide solution until the appearance of pink coloration, persisting for 30 seconds. The analysis and calculation were carried out according to the Adolf Lutz Institute [16] and Resolution RDC 482/1999 of the National Agency of Sanitary Surveillance [3], which determines the acidity index for crude sesame oil in g of oleic acid / 100g.

Acidity in oleic acid = v x f x M x 28.2 / P, where,

V = number of mL of sodium hydroxide solution 0.1 M spent in the titration.

F = correction factor of sodium hydroxide

P = sample g number

The determination of the peroxide index was performed according to the analytical norms of Adolfo Lutz Institute [16]. 5g of the sample was weighed in an AW 220 analytical balance in triplicate in a 250 mL Erlenmeyer flask and 30 mL of 3: 2 acetic-chloroform solution was added and shaken until complete dissolution of the sample. Then, 0.5 ml of the potassium iodide (KI) saturated solution was added and the sample was allowed to stand out from the light for exactly 1 minute. 30 mL of water was added and finally the titration was carried out with 0.01 N sodium thiosulphate solution, with constant stirring until the yellow color had almost disappeared. Then 0.5 ml of indicator starch solution was added and the titration continued until the complete disappearance of the blue coloration. A blank test was prepared under the same conditions quoted and titled at the end.

Peroxide content in meq per 1000 g of the sample = (A-B) x N x f x 1000 / P, where:

A = mL number of 0.01N sodium thiosulphate solution spent on sample titration

B = mL number of the 0.01N sodium thiosulfate solution used in titration of the blank

N = normality of sodium thiosulphate solution

F = factor of sodium thiosulphide solution

P = sample g number

Determination of Vitamin E: The alpha-tocopherol type of vitamin E was determined by HPLC (High Performance Liquid Chromatography) in a single analysis [17].

Statistical analyzes

The results were submitted to analysis of variance (ANOVA), with Tukey's post test to compare the means between the groups. To compare only two groups, the t-test was used. The confidence interval was 95%. The GraphPad Prism 5.

Results and discussion

Table 1 shows the fatty acid profile of crude sesame oil, which is in accordance with the recommendations recommended by Anvisa [3], with the exception of stearic acid, which presented a lower value than that recommended in the legislation that allows this saturated fatty acid to be up to 6g / 100g, and therefore not considered relevant to our study. The alpha-linolenic unsaturated fatty acid presented values higher than those recommended by the legislation. The oil is considered an important source of polyunsaturated fatty acid linoleic (omega-6), oleic monounsaturated fatty acid (omega-9) and small amount of polyunsaturated fatty acid linolenic (omega-3). In relation to saturated fats, the palmitic and stearic acids are those found in greater amounts.

On the effects of saturated fatty acids on the lipid profile and on cardiovascular risk factors, it is known that

lauric fatty acid may increases LDL-c, as well as myristic fatty acid. This meta-analysis also showed that stearic fatty acid may cause small reduction in LDL-c [18]. The first fatty acid was not found in crude sesame oil and the second in small quantities in all products and in sesame oil, presented within the recommended by the legislation [3]. Another study found 14.59% of lauric acid in sesame oil [19]. However, sesame as well as other vegetable oils did not present lauric acid in their composition [20]. Antoniassi et al. (2013) analyzed sesame oil in different regions and did not present lauric acid data [21].

Table 1: Fatty acid profile of Crude Sesame Oil

Table 1: Fatty acid profile of Crude Sesame Oil		
Fatty acid profile	**Sesame oil (%)**	**g/100g (RDC/482)***
Ethereal extract	99,71 ± 0,18	UE
Saturated fatty acid		
Caprylic (C 8:0)	0,02 ± 0,00	UE
Myristic (C 14:0)	0,04 ± 0	< 0,5
Palmitic (C 16:0)	11,49 ± 0,04	7,0 -12,0
Margaric (C 17:0)	0,05 ± 0,00	UE
Stearic (C 18:0)	2,64 ± 0,01	3,5 - 6,0
Arachidonic (C 20:0)	0,52 ± 0,01	< 1,0
Behenic (C 22:0)	0,23 ± 0,01	< 0,5
Ticosanic (C 23:0)	0,04 ± 0,00	UE
Lignoceric (C 24:0)	0,22 ± 0,00	UE
Total (*Saturated fatty acid*)	15,25	
Monounsatured fatty acids		
Palmitoleic (C 16:1)	0,14 ± 0,01	< 0,5
Oleic (C 18:1)	35,32 ± 0,27	35,0 - 50,0
Erucico (22:1 n9c)	0,02 ± 0,00	NE
Total (*Monounsaturated fatty acid*)	35,48	
Polyunsaturated fatty acids		
Linoleic (C 18:2)	47,62 ± 0,19	35,0 / 50,0
Alpha-linolenic (C 18:3)	1,25 ± 0,05	< 1,0
Eicosenoic (C 20:1)	0,25 ± 0,01	< 0,5
Cys-Eicosadienoic (C 20:2)	0,01 ± 0,01	NE
Total (*Polyunsaturated fatty acids*)	49,13	
Mean ± Standard Deviation; UE = unspecified *Resolution RDC No. 482 of September 23, 1999 (BRAZIL, 1999)		

Antoniassi et al. (2013) analyzed the fatty acid profile of sesame oil from two different regions, Patos, in Paraíba and in Bartalha, no Ceará and found higher values than those found in our study for stearic fatty acid, being 5.36%, in Patos and 5,74% in Bartalha, and for palmitic acid, 10%, in the two analyzed regions [21]. In relation to the effects of saturated fatty acids on the lipid profile and cardiovascular risk factors, it is known that lauric fatty acid may increases LDL-c, as well as myristic fatty acid. This meta-analysis also showed that stearic fatty acid may cause small reduction in LDL-c [18]. Stearic acid is present in sesame oil, according to the results presented in our study.

Guimarães et al. (2013) observed that sesame oil has a higher concentration of saturated palmitic fatty acid compared to stearic saturated fatty acid [19]. In relation to unsaturated fatty acids, sesame oil is richer in oleic monounsaturated fatty acid and polyunsaturated fatty acid linoleic (omega-6). Comparing these results with those found in our study, we found higher values of oleic fatty acid (35.32%) compared to 28.59% of linoleic acid, we found 47.62%, while Guimarães et al. (2013) found a lower value than ours (28.35%) [19]. we found that sesame oil has a low content of alpha-linoleic acid (1.25%) in our study.

According to the I Guideline on fat consumption and cardiovascular health, (2013), dietary factors are related to the incidence of cardiovascular diseases, mainly in relation to the consumption of different types of fat, since they interfere in the appearance or not of atherosclerotic events. It is known that consumption of saturated and trans fat is related to elevated LDL-C levels and increased cardiovascular risk, whereas the presence of mono and polyunsaturated fats in the diet is important for the control of hypercholesterolemia and consequently, reduce the chances of cardiovascular events [22].

This way, fatty acids can promote or prevent the onset of atherosclerosis, according to the effects on serum cholesterol levels and Low-Density Lipoprotein (LDL) concentrations. In this context, it is suggested as a measure to verify the influence of diet on the incidence of cardiovascular diseases, atherogenicity index (AI) and Thrombogenicity Index (TI). AI considers the saturated fatty acids lauric, myristic and palmitic in relation to unsaturated fatty acids; TI considers myristic (C14: 0), palmitic (C16: 0) and stearic (18: 0) saturated fatty acids as thrombogenic and poly-unsaturated fatty acids omega 3 and monounsaturated fatty acids with antithrombogenic effects [14]. These indices may indicate the nutritional quality of oils and fats and their possible benefits or harm to cardiovascular health, since they indicate the potential for stimulating platelet aggregation [23].

Crude sesame oil had AI of 0.14 and TI of 0.07 (Table 2). Guimarães et al. (2013) found values of the AI and TI indexes in sesame oil of 0.69 and 0.13, respectively [19]. Ulbricth and Southgate (1991) reported the following TI values in different types of vegetable oils: 6.18 in coconut oil, 1.74 in palm oil and 0.32 in olive oil [14]. In relation to AI, the crude sesame oil analyzed in this study was considered zero value related to lauric acid, since no saturated fatty acid was detected in our study and, according to other studies, it was also not found in the fatty acid profile of sesame oil [20, 21]. Guimarães et al. (2013) found 14.59% of lauric fatty acid in the sesame oil analyzed in their study [19].

Crude sesame oil presented low values in relation to the indices of nutritional quality (AI and TI), and can therefore be considered an oil that offers cardiovascular health benefits. According to Turan, et al. (2007), lower values of AI and TI indicate that there is a greater amount of anti-atherogenic and anti-thrombogenic fatty acids in the oil or fat and, therefore, may be considered an important food in the prevention of cardiovascular diseases [23]. These elevated indices are considered risk factors for cardiovascular diseases and when food presents values lower than 1, they may present cardio protective effects [24].

The ratio between PUFA and SFA was 3.22. According to London (1984), values up to 0.45 are considered inadequate, since they are related to the higher increase in cholesterol levels [15]. In the present study, therefore, the value of 3.22 is considered excellent, showing that crude sesame oil has nutritional quality because it has a higher number of polyunsaturated fatty acids when compared to the amount of saturated fatty acids, according to what is reported by London [15]. Guimarães et al. (2013) found 0.79 in PUFA / SFA ratio in sesame oil [19]. This value is lower than our present study, but also considered adequate in relation to cardiovascular health.

Another important data regarding the polyunsaturated fatty acids in sesame and that analyzes its nutritional quality is the ratio omega-6 / omega-3 found in the oil that was 38 (Table 2), since the sesame is rich in omega-6 and has little amount of omega-3.

This relationship is reported by the I Guideline on Fat Consumption and Cardiovascular Health, which discusses the role of this relationship in the diet on cardiovascular diseases, since it is considered a lot of controversy 22. Due to significant changes in diet in relation to intake of fatty acids, there was increased consumption of cereals, grains and oils sources of omega 6, besides a reduction in the consumption of food sources of omega 3 fatty acids. Of 15: 1 to 40: 1 in western feed [25, 26]. Santos et al (2013) report that this increase would make the formation of inflammatory factors related to obesity, diabetes and cardiovascular diseases higher [22]. However, if there is substantial evidence on the one hand side of the relationship between increased consumption of omega-3 source foods and cardiovascular protection, on the other hand, there is no scientific evidence that reducing omega-6, alone, would make the risk of cardiovascular disease decrease [27]. In addition, both fatty acids have cardiovascular health benefits and are considered essential fatty acids [6, 28].

Table 2: Nutritional quality of crude sesame oil

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Perfil de ácidos graxos	**Óleo de gergelim**
Atherogenicity index (AI)	0,14
Thrombogenicity index (AI)	0.07
PUFA:SFA ratio	3,22
ω6:ω3 ratio	38

It's important to highlight that although sesame is richer in omega 6 than in omega 3, it is a food rich in oleic monounsaturated fatty acid. Diets containing monounsaturated fatty acids make LDL less susceptible to oxidation and may result in inhibition of the atherogenic process [29]. A systematic review and meta-analysis of epidemiological studies and randomized controlled trials showed that adherence to dietary pattern, such as the Mediterranean diet, has cardiovascular protection effects and it is known that this diet is characterized by high consumption of monounsaturated fatty acids [30].

According to the recommendations of the I Guideline on fat consumption and cardiovascular health, the consumption of saturated, monounsaturated and polyunsaturated fats should be <7%, 20% and 6% to 10%, respectively, of the total caloric value of the diet [22]. DRIs recommend the daily intake of essential fatty acids linoleic, from 14 to 17 g for men and 11 to 12 g for women, and linolenic 1.1 g for women and 1.6 g for men [31].

Table 3 shows that the values obtained for the acid and peroxide indices are in accordance with the recommendations for crude sesame oil recommended by Resolution RDC n. 482 of September 23, 1999 of Anvisa [3], suggesting an adequate standard of identity and product quality of the present study.

Table 3. Identity and quality standards of Crude Sesame Oil.

Table 3: Identity and quality standards of Crude Sesame Oil.		
	Crude Sesame Oil	RDC/482*
Acid Index (g oleic acid/100g)	0,92 ± 0,09	Maximum 2,0
Peroxide Index (meq/Kg)	8,99 ± 0,98	Maximum 10
Mean ± Standard Deviation. *Resolution RDC No. 482 of September 23, 1999 of Anvisa		

According to RDC Resolution No. 482 of September 23, 1999 [3], sesame oil is "the edible oil obtained from Sesamum indicum L. seed by appropriate technological processes" and crude sesame oil is the "oil obtained by the extraction process ". The oil that was analyzed in this work is characterized as raw, cold-pressed, unrefined and extra-virgin sesame oil, according to manufacturer's information. The process of extraction of this type of oil, according to Queiroga and Silva (2008) is carried out directly in the whole grains, by means of 4 steps: roasting of the grains, steam cooking, pressing and filtration.

In relation to the results presented in this study, the sesame oil presented an excellent pattern of identity and quality [3], suggesting that this one presents greater conservation, low rancification and adequate oxidative stability.

Lipid oxidation can cause deterioration and loss of product quality, resulting in unpleasant flavors and odors for food, as well as changes in nutritional quality, color, aroma and texture. This process can cause degradation of fat-soluble vitamins and essential fatty acids, in addition to affecting the integrity of the

food product, making it unfit for consumption [32, 33]. Some external compounds such as light, temperature and storage time also interfere in this quality [34].

Therefore, this guarantee of oxidative stability found in crude sesame oil is very important. The appropriate peroxide index, which is the important indicator of the oxidative process, and with values within what is recommended by Anvisa [3], will guarantee the quality of the oil.

It is suggested that this low oxidation of sesame oil can be explained by the presence of vitamin E found in the oil in our study, which was 28.34 mg / 100 mL. In relation to vitamin E, it is known that this is an important nutrient in relation to the antioxidant defense [35], being responsible for inhibiting or reducing the damage caused by reactive oxygen species (ROS) [36].

Thus, sesame oil may be associated with the improvement of oxidative stress as shown by some scientific evidence [8]. Guinaz et al. (2009) analyzed the vitamin E content in vegetable oils and observed that canola oil had the highest alpha-tocopherol content (18.39 mg / 100 mL) when compared to soybean oil (12.14 mg / 100 mL) and extra-virgin olive oil (14.05 mg / 100 mL) [37]. Our findings found 28.34 mg / 100mL of vitamin E in sesame oil, showing that it has a higher content of vitamin E when compared to the vegetable oils analyzed by Guinaz et al. [37]. It is known that antioxidant chemicals are added to vegetable oils in order to inhibit or retard their lipid oxidation. The most common synthetic antioxidants used by the food industry are: BHA, BHT, PG and TBHQ and, among natural antioxidants, tocopherols are the most widely used [33]. The crude sesame oil used in this work had no increase in natural or synthetic antioxidants, according to the product label information.

In a study that evaluated the antioxidant activity of sesame extract of sesame oil in soybean and sunflower oil, it was observed that this reduced significantly the peroxide index in the studied vegetable oils, besides indicating that low concentrations of sesame extract presented better antioxidant effect when compared to the use of BHT [38].

According to the clinical trials that used sesame oil in their populations, the recommendation of daily consumption would be 35 g per day in order to obtain beneficial effects to human health [39, 40, 41, 42]. This amount would represent 2 + ½ tablespoons of raw sesame oil, measured in our study, which has 9.92 mg of vitamin E, which corresponds to 66.13% of the daily recommendation of this vitamin. Is 15 mg / day for men and women [43]. Thus, we can say that sesame oil is a source of vitamin E, since the legislation determines that reaching at least 15% of the DRI of vitamin, the product is considered source of this nutrient [44].

In a study with vegetable oils, sesame oil presented greater oxidative stability when compared to flaxseed oil [19], which may have as an explanation the presence of natural antioxidants, such as sesamin, sesamol and sesamolin, which are specific sesame's lignans [45, 5], which ensure higher stability to unsaturated fatty acids [2], in addition to high antioxidant activity [46].

Moazzami et al. (2006) analyzed the lignan content in seeds and sesame oil and observed that the main components are sesamin (8.80 mg / g seed and 6.20 mg / g oil) and sesamolin (4.50 mg / g of seed and 2.45 mg / g of oil), without significant differences between the white and black seed according to the authors [47].

Due to the high content of this fatty acid and the presence of natural antioxidants, such as vitamin E and lignans, sesame is considered an oil that is more resistant to oxidation and low rancification [4, 5].

Conclusion

Sesame oil had important nutritional quality indexes in relation to cardiovascular health, since AI and IT were low and the ratio between PUFA and SFA was considered adequate when compared to other studies. In addition, the sesame oil presented an identity and quality standard in compliance with the legislation, with adequate peroxide and acidity indexes, indicating that it is a kind of oil with good oxidative stability and low rancification.

Regarding the clinical applicability, the consumption of sesame oil could be stimulated by an important source of unsaturated fatty acids and vitamin E according to the observed results. Clinical trials with sesame already showed their effects on lipid profile, blood pressure and oxidative stress. The results of these studies can be explained by the composition of unsaturated fatty acids present in sesame and the content of insoluble fibers. In addition, the concentration of vitamin E in sesame oil makes it work in the improvement of oxidative stress, avoiding or decreasing the formation of ROS and assisting in the improvement of the lipid profile. Other studies need to be performed in relation to nutritional quality indexes, as there are still few studies that analyze the rates of atherogenicity and thrombogenicity.

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