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Physicochemical Properties, Heavy Metals and Aflatoxin in Sesame Oil: A Review Study

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ABSTRACT

Introduction: The present study aimed to review the articles on determining the physicochemical properties of sesame oil in terms of the levels of heavy metals and aflatoxins without geographic restriction.
Methods: Literature review was performed via searching databases such as Google Scholar, Pub Med, Science Direct, and SID. Based on properties such as iodine value and fatty acid profile, sesame oil has been reported to be highly unsaturated. In addition, the most important unsaturated fatty acids include oleic acid and linoleic acid, which constitute80-84% of the fatty acids found in sesame oil. The key feature of sesame oil was resistance against oxidative damage despite its high unsaturated fatty acid content. The oxidative stability of sesame oil is caused by the presence of gamma-tocopherol, lignans, and antioxidants (e.g., sesamol, sesamin, and sesamolin).
Results: According to the reviewed articles, total aflatoxin level in sesame oil was less than the recommended limit by the European Union(EU) (20 µg/kg), with the exception of the study by Amin et al. (2010), in which total aflatoxin level was reported to be higher than the EU limit. In the reviewed studies, arsenic and lead levels were below the recommended EU limit (0.1 mg/kg). Additionally, the levels of copper and iron were reported to be below the national standard level in Iran (0.4 and 5 mg/kg, respectively).
Conclusion: Considering the beneficial properties of sesame oil and its high degree of unsaturation, it is recommended that the levels of heavy metals aflatoxins be monitored regularly to consume this healthy vegetable oil.

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Introduction

Fats and oils are the nutrients that supply energy and play a key role in survival and health. Oils are an inherent element in human nutrition since they have the highest energy levels compared to other nutrients. Oils contain vitamins A, D, E, and K, while they also provide the essential fatty acids that cannot be produced by the human body (e.g., linoleic acid and alpha linolenic acid).

Most herbal oils and crude fats are consumed after the necessary procedures to eliminate their impurities. Fats and oils are essential nutrients not only from the health perspective, but also in terms of trade. As such, it is necessary to survey the production and consumption of fats and edible oils. Oilseeds are the largest production source of vegetable oils; such examples are soybeans, sunflowers, canola, corn, cottonseed, peanuts and sesame. (1).

Sesame *(Sesamum indicum L.)* is an oil crop that belongs to the *Pedaliaceae* family. Sesame seed is considered to be one of the most important oily seeds in developed countries. Approximately 60% of the annual production of sesame seed is in India, China, Sudan, and Mexico. China is currently the world's largest producer of sesame (2). Sesame is a major oilseed, which contains 45-50% oil. In fact, about 70% of the produced sesame in the world

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is used for oil extraction. Sesame oil is used in the preparation of food, cosmetics, and pharmaceuticals. In Asian countries, sesame has historically been thought to be a beneficial nutrient for human health (3).

Black sesame seeds have been shown to have antihypertensive effects in the patients with hypertension. Such effects of sesame seeds are associated with the presence of lignans (sesamol and sesamolin), as well as the to copherol residues in black sesame seeds after oil extraction (4). Antioxidants protect cells against oxidative damage due to their high affinity to oxygen, thereby preventing cancer, disorders associated with aging, and cardiovascular diseases (5).

The chemical composition of sesame shows that the seed is an abundant source of oil (44-58%), protein (18-25%), carbohydrates (13.5%), and ash (5%)(6). Moreover, sesame oil is a rich source of minerals, especially calcium, phosphorus, potassium, and iron, the levels of which vary depending on species, color, and size of the plant. Sesame also contains oleic and linoleic acids (6), while sesame oil is rich in unsaturated fatty acids (85%) and has a mild taste. In addition, sesame contains large amounts of oleic (43%), linoleic (35%), palmitic (11%), and stearic acid (7%), which constitute 96% of the total fatty acids altogether (7).

Considering the rising trend of the consumption of vegetable oils, especially sesame oil, it is paramount importance to identify the properties of sesame oil, as well as its effects on human health. The present study aimed to review the current literature on the physicochemical properties of sesame oil and the published articles regarding the level of aflatoxins and heavy metals in sesame oil.

Material and methods

Literature review was conducted via searching for the studies focusing on the properties of sesame oil in databases such as Google Scholar, Science Direct, Pub Med, and SID without geographic restriction using various keywords, including sesame oil, physicochemical, oxidative stability, heavy metals, and aflatoxins .Afterwards, the studies that examined the physicochemical properties and levels of heavy metals and aflatoxins in sesame oil were selected and further evaluated.

Results and Discussion

Findings of the studies regarding the physicochemical properties and fatty acid composition of sesame oil in percentage are presented in Tables1-3.

Table 1. Physicochemical Properties of Sesame Oil

Reference	FFA	PV	IV	AV
(8)	0.92±0.2	2.7±0.5	117±0.5	-
(9)	-	0.220-22.55	-	0.743-3.680
(10)	2.0±0.115	1.20±0.011	110±1.555	-
(11)	-	-	101.7	-
(12)	2.24±0.07	6.0±0.25	112.21±0.38	4.488±0.06
(13)	-	8.12±0.87	-	0.75±0.04
(14)	0.937	0.5-3.4	-	-
(15)	-	5.55±1.01	97.11±3.80	0.59±1.15
(16)	0.34-1.43	1.01-7.61	76.14-130	0.67-2.85
(17)	0.36-0.66	1.7	110.07	-
(18)	-	8	103	0.5
(19)	-	1.90±0.2	111.5±1	0.4±0.01
(20)	0.82±0.01	0.14±0.01	113.3±0.59	1.64±0.02
(21)	-	1.42±0.69	-	0.11±0.06
(22)	0.41±0.02	5.42±0.02	116.48±0.05	-

FFA (as oleic acid; %): free fatty acid; IV (I2/100 g): iodine value; PV (meq O_2/kg): peroxide value; AV (mg KOH/g of oil): acid value

Table 2. Physicochemical Properties of Sesame Oil

Reference	SG	RI	SV
(8)	-	1.472 (20°C)	-
(9)	0.9535-0.9153	1.471-1.474(30°C)	-
(10)	0.915±0.001 (28O°C)	1.4565±0.00005 (28O°C)	-
(12)	0.910±0.02	1.471±0.03 (25°C)	192.24±0.92

(14)	-	1.472	-
(15)	-	-	190.6±0.011
(23)	0.877	1.473	189.6
(17)	0.93	1.4713	195.04
(18)	0.915	-	189
(20)	-	1.471 (20°C)	186.6

RI: refractive index; SG: specific gravity; saponification value (mg KOH/g of oil)

Table 3. Fatty Acid Composition of Sesame Oil (%)

Reference	Palmitic Acid	Stearic Acid	Oleic Acid	Linoleic Acid	SFA (mg/100 mg)	UFA (mg/100 mg)
(8)	11.3±0.1	11.3±0.1	41.9±0.1	42.1±0.1	16.3±0.2	84.3±0.2
(10)	9.0	4.3	44.0	40.3	15.4	83.2
(11)	10.06	5.14	40.18	43.46	-	84
(12)	12.90	4.15	43.59	38.53	17.05	82.95
(13)	10.0±0.1	5.2±0.1	36.3±0.3	44.2±0.5	17.1	81.4
(14)	7.9-11.4	4.8-5.8	39.3-42.1	42.5-46.3	16	84.3
(23)	10.57	3.5	44.37	40.23	-	-
(19)	9.5±0.26	5.6±0.45	42.4±1.07	40.10±0.25	15.43	84.67
(20)	12.96±0.06	5.76±0.06	41.68±0.61	38.29±0.24	19.25±0.13	78.82
(21)	10.4±1.3	5.3±0.8	39.5±0.9	42.9±1.8	16.7	83.2
(22)	8.75	5.05	36.97	47.18	-	-

Aflatoxin Levels

The presence and growth of fungi may lead to the corruption and poor quality and quantity of food products. Aflatoxins (AF) B_1, B_2, G_1, and G_2 are among the main contaminants of cereals, spices, coffee, ground, pistachio, and various oilseeds, including sesame seeds. Among AFs, AFB_1 has the highest natural potential to cause liver cancer, and its risk assessment it thoroughly known (24).

According to the literature, the quantity and quality of the oil content of sesame seeds depend on environmental, genetic, and physiological factors, such as the climate, type of soil, cultivars, and maturity (10). The risk of AF contamination has been reported to be higher in the grains exposed to water pressure, high temperature of the environment, mechanical damage during harvest, insect sting, rainfalls during harvest, and storage in warm and humid conditions. In the grains with mechanical damage during harvest or by insects, mildew growth is highly common. Furthermore, warm and humid environments accelerate the growth of mold. To date, AFs have been isolated from various grains, including corn, barley, wheat, and rice, as well as oilseeds (e.g., peanuts, soybean, cotton, sesame, and sunflower) and their extracted oils (25).

Aspergillus is considered to be the most common toxigenic species in various grains, legumes, and oil seeds. Oilseeds, especially peanuts, are susceptible to *Aspergillus* growth. The highest rate of AF contamination in these products has been reported before and after harvest and during storage (26).Table 4 shows the studies that have examined the level of AF sin seeds and sesame oil. In all the studies focusing on AFs, *Aspergillus* infection has been denoted.

In the studies by Idris Yam et al. and Elzupir A.O. et al., the level of $AFB_1$was reported to be higher than the recommended limits by EU and the National Iranian Standard Institute (5 µg)in foodstuffs (2 µg). Moreover, in the research by Elzupir A.O. et al., total AFs were observed to be higher than the standard levels of the Food and Drug Administration (FDA) (20 µg) and the National Iranian Standards Organization (15 µg) (9,28).On the other hand, Elzupir et al. denoted the highest level of AFB_1. In Sudan, the level was estimated at 43.6 µg/kg, which could be due to the production of sesame from the small wringers that were preserved at poor temperature and humidity.

Table 3. Aflatoxin Content in Sesame Seeds and Oil

Reference	AFB_1	AFB_2	AFG_1	AFG_2
(9)	0.5-9.8 µg/kg	0.5-1.3µg/kg	0	0
(27)	43.6 µg/kg	0.3 µg/kg	47.5 µg/kg	102.7 µg/kg
(28)	0.2-0.8 µg/kg	0	0	0
(24)	1.62±1.32ng/g in Sesame Seeds	0.33±0.07ng/g Sesame Seeds	1.10ng/g Sesame Seeds	0.25 ng/g Sesame Seeds

Heavy Metals

Soil contamination with heavy metals not only reduces the quality of food products and food safety and contaminates surface water, but it also poses great risk to the health of animals and humans since heavy metals could be transferred into the chain food (soil-plant-human or soil-plant-animal-human)(29). The trace elements in plants and their chemical forms in edible oils might be affected by the soil in which they are grown, as well as environmental exposure to these elements, stages of oil extraction and treatment or contamination caused by the equipment used for metal processing. Furthermore, essential metals may exhibit toxic effects with the excessive elevation of metal intake. Elements such as copper, zinc, manganese, and iron have been reported to increase oil oxidation, while copper and iron catalyze the decomposition of hydroperoxides, thereby leading to the formation of hazardous substances in oils.

Lead, arsenic, mercury, and cadmium are toxic heavy metals found in oils (30). It is well-established that heavy metals have adverse effects on the nutritional value, toxicity, and oxidative stability of oils. Therefore, it is critical to determine the concentrations of heavy metals in various oils (31).The results of the studies examining the concentrations of heavy metals in sesame oil are presented in Table 5.

Table 5. Concentrations of Heavy Metals in Sesame Oil

Reference	Cadmium	Lead	Iron	Copper	Zinc	Manganese	Arsenic
(14)	0.11 mg/kg	0.04±0.02 mg/kg	0.23±0.05 mg/kg	0.02±0.01 mg/kg	0.16±0.39 mg/kg	0.12±0.08 mg/kg	-
(30)	5.44±0.28 ngg^{-1}	0.018±0.02 µg g^{-1}	38.5±2.3 µg g^{-1}	0.039±0.003 µg g^{-1}	0.883±0.067 µg g^{-1}	0.184±0.014 µg g^{-1}	0.019±0.001 µg g^{-1}
(32)	5.78±0.21 ng g^{-1}	0.017±0.002 µg g^{-1}	43.8±4.7 µg g^{-1}	0.049±0.003 µg g^{-1}	0.955±0.071 µg g^{-1}	0.269±0.002 µg g^{-1}	0.018±0.001 µg g^{-1}

Oxidative Stability

Evaluation of the stability of oils using the Rancimat method is considered to be a direct measure of the changes in the oxidation resistance of oils. By measuring this parameter indifferent types of oil, it is possible to compare the degree of deterioration in oils during heating (33). Prioritization of the oils and fatty products with fresh, mild flavors and odors requires quality and rancidity assessment during development and after processing (34).

Oxidation results in the progressive assemblage of odorless molecules (e.g., hydroperoxides) and secondary products (35). Hydroperoxides are the initial products of autoxidation, and their analysis leads to the formation of an extensive range of carbonyl compounds, hydrocarbons, furans, and other products, intensifying rancid odors and off flavors (36).

Lipid oxidation has been recognized as the main issue affecting the chemical, sensational, and nutritional properties of edible oils (37). Previous studies have indicated that the oxidative stability of oils and their byproducts is associated with the applied processing techniques and variety of the seeds. In addition, the findings in this regard have emphasized on the key role of seed variety in the quality and contents of oils. According to a report, black sesame seeds contained less oil compared to the white- and brown-seeded strains of sesame. Such differences have also been observed in sesam in content (38).

Among the commonly used vegetable oils, sesame oil is considered to be most resistant to oxidative rancidity (39).The main properties of sesame oil in this regard are resistance to oxidative damage despite its high unsaturated fatty acid content (70%). The oxidative stability of sesame oil is attributed to the presence of gamma-to copherol, lignans, and antioxidants (e.g., sesamol, sesamin, and sesamolin) (40).The results of the studies focusing on the oxidative stability of sesame oil are shown in Table 6.

Table 6. Oxidative Stability of Sesame Oil

Reference	Oxidative Stability
(19)	19.94 h (110°C)
(8)	28.5±0.5 h (110°C)
(22)	611.40±0.85min (110°C)
(34)	38.37±16.02 h (110°C)

Conclusion

Sesame is one of the most important oilseed crops in the world, which plays a pivotal role in human feeding and has numerous medicinal, pharmaceutical, industrial, and agricultural applications. Sesame seeds are an abundant source of copper and calcium, as well as phosphorus, iron, magnesium, manganese, zinc, and vitamin B_1. The medicinal and health benefits of sesame may be attributed to its laxative, emollient, and soothing properties. Sesame contains 44-58% edible oil, which is of high quality and could be used as salad dressing with low or no winterizing.

According to the literature, the quantity and quality of the oil content of sesame seeds depend on various environmental, genetic, and physiological factors, such as the climate, type of soil, cultivars, and plant maturity. The oil fraction represents a significant oxidative stability, which could be attributed to the presence of endogenous antioxidants (sesamol, sesamolin, andsesamin) and tocopherols. Sesame oil has superior oxidative stability despite its high level of unsaturation; this quality could be due to the presence of gamma-tocopherol, lignans, and antioxidants.

The optimal acid content in vegetable oils should be less than 2.0(15), and the maximum acceptable level of acid value has been set at 6 mg KOH/g of oil by FAO. In addition, fresh oils often have peroxide values of less than 10 $meqO_2$/kg of oil (41).According to the results of the reviewed studies on sesame oil, the acid and peroxide values and percentage of free fatty acid sin sesame oil are at an acceptable level. These findings indicate that sesame oil is resistant to enzymatic spoilage and rancidity caused by oxidation. Moreover, the iodine value of sesame oil is within the range of 76.14-130.07, classifying it in the category of semi-drying oils (42). The reviewed studies also demonstrated the high iodine value of sesame oil. In the nutritional viewpoint, high iodine value is desirable since it indicates the high levels of unsaturated fatty acids in sesame oil. On the other hand, the findings on the iodine value confirm the high degree of unsaturation in sesame oil, which is associated with the results of the assay oil fatty acid profile.

The saponification value of sesame oil (200 mg KOH/g) indicates the high ratio of fatty acids with low molecular weight (43). Therefore, it could be inferred that sesame oil lacks the potential application in the soap industry. In is notable that the thermal stabilization of poly vinyl chloride and AF levels, especially AFB_1, in sesame oil are alarming, and further monitoring is required to reduce the associated health risks.

Metals such as copper, zinc, iron, and manganese are essential elements since they play a key role in the biological functions of the human body. Metallic content is one of the most important criteria for the quality of vegetable oils. The presence of metals in vegetable oils is due to the internal environmental factors associated with plant metabolism and external factors, such as contamination during agronomy, production, and collection, oil extraction and processing, packaging materials, and storage systems. Moreover, the presence of elements such as lead and cadmium in food products is a public health concern since it is associated with the risk of toxicity for humans, particularly children, who are more susceptible to these metals compared to adults.

In the reviewed studies, arsenic and lead levels were reported to be below the recommended limit by the EU and National Iranian Standards Organization (0.1 mg/kg). Additionally, the levels of copper and iron were below the national standard level of Iran (0.4 and 5 mg/kg, respectively). Considering the beneficial properties of sesame oil and its high degree of unsaturation, it is suggested that the AF levels be monitored continuously in the case of heavy metal contents in order to produce a high-quality vegetable oil for human consumption.

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