Nutrition and Food in Health and Disease Vol 12, No 3, Jul-Sep 2025, pages:41-50

Original Article

Investigating Fatty Acids, Triglycerides and Physicochemical Characteristics of Ostrich Oil for Human Nutrition

Alireza Bahonar*[1], Asghar Azizian[1], Mojtaba Ayaz[2], Norallah Nikkhah[3]

1- Department of Food Hygiene and Quality Control, Faculty of Veterinary Medicine, University of Tehran, Tehran, Iran

2- Director of the Ostrich Consulting Center

3- CEO of the Iranian Ostrich Breeders Cooperative Company

Received: January 2025 **Accepted:** April 2025

ABSTRACT

Background and Objectives: Ostrich oil is a valuable source for use as edible oil in the food industry and production of cosmetic products due to its high nutrients and contents of essential fatty acids. However, the quality of ostrich oil is important for use in products containing this oil.

Materials and Methods: In methods of this study, ostrich oil in liquid and solid phases was first extracted from tallow by wet melting. Then, their physicochemical characteristics including iodine number, moisture, hexane residue, peroxide value, volatile matter, saponification number, un-saponifiable matter, stability, acidity, melting point, smoke point, refractive index, specific weight, quantity of α-tocopherol (vitamin E) were assessed. In addition, fatty acid composition and triglyceride content were assessed. All experiments in this study were carried out in triplicate based on valid methods. The means were compared with independent sample T test ($P \leq 0.05$).

Results: Results of peroxide value and free fatty acid tests showed efficiency of the fat extraction method. Results also showed that this oil contained high quantities of α-tocopherol that can protect the oil against oxidation and its most important fatty acid is oleic acid (36.99 mg ml^{-1} in liquid oil and 37.40 mg g^{-1} in solid oil.

Conclusions: Based on the findings of this study, ostrich oil with high contents of unsaturated fatty acids, acidity, melting point and smoke point, makes it appropriate for introduction and use in the food industry (production of frying products due to its appropriate smoke point and high-fat products due to its high antioxidant content). Therefore, use and consumption of this oil as edible human oil is recommended.

Keywords: Ostrich oil, Physicochemical characteristics, Edible oil

Highlights

- Ostrich oil includes high contents of unsaturated fatty acids
- The value of peroxide in liquid ostrich oil (4.54 ±0.01 mEq. O_2 kg^{-1}) is 2.67-times higher than solid ostrich oil
- Ostrich oil (liquid and solid oils) contains alpha-tocopherol
- Results of this study showed that the Saponification number of ostrich oil is close to the saponification number of corn (187–195), palm (190–202) and safflower (186–198) oils

Introduction

Edible oil is an essential part of the human daily diet structure and active lipid substances in edible oil includes a positive effect on the prevention and treatment of cardiovascular and cerebrovascular diseases (1). The flightless ostrich (*Struthio camelus*) is the largest bird worldwide and is adapted to living in warm countries such as Thailand and Australia. This bird was originally

***Address for correspondence:** Alireza Bahonar, Prof, Department of Food Hygiene and Quality Control, Faculty of Veterinary Medicine, University of Tehran, Tehran, Iran. E-mail address: abahonar@ut.ac.ir

[DOI: 10.61882/nfsr.12.3.41]

domesticated for the purpose of producing leather but now bred mostly for the production of meat and oil (2–3). The quantity of fat in the carcass depends on the type of animal and its breed and there is a significant quantity of fat hidden in the muscles. The fat in ostrich carcasses is located in certain storage places, including the abdomen, below the sternum and between the muscles (4).

Ostrich oil from ostrich adipose tissue is majorly composed of triglycerides and essential fatty acids (EFA), especially alpha-linolenic acid (ALA) and linoleic acid (LA). High levels of unsaturated fatty acids (UFA) in ostrich oil can be a good source of EFAS in the human diet (5). In 2017, Basuny et al. assessed the biological characteristics of ostrich oil and its uses as a novel source of animal fats in biscuit production. Their results showed that ostrich oil nutrition included no effects on liver and kidney functions and serum contents and the characteristics of baked biscuits were improved by replacing ostrich oil (6).

The ability of ostrich oil to defend and protect membranes against oxidative stress is linked to its fatty acid (FA) composition. However, the antioxidant activities of ostrich oil may be due to their FAs, vitamins and amino acids (AA) (5). The major constituents of natural UFAs and antioxidants in ostrich oil can be used as a healthy food as well as a good moisturizer (e.g. leucines and creams) (2, 7). Ostrich oil contains various compounds such as carotenoids, tocopherols and flavonoids and hence includes therapeutic benefits. In addition, ostrich oil includes characteristics such as antibacterial, anti-inflammatory and skin protection (2, 5, 7–8). Although the ostrich breeding industry in Iran is developing and due to the high economic values of ostrich breeding and unique characteristics of the bird's oil, a little information are available on ostrich oil. Therefore, the purpose of this study was to investigate physicochemical characteristics of liquid and solid samples of ostrich oil, including saponification number, acid index, peroxide index, FA composition and oil triglyceride composition used as edible oil in the food industry.

Materials and Methods

Extraction of ostrich oils

As shown in Figure 1, ostrich fat tissue was transported to the laboratory for lubrication after extraction and cleaning at cold temperature (with ice) for testing. Fat tissue was dried before lubrication in the developed processing method at low temperatures. Wet melting was carried out with moist heat at 100 °C for 4 h using autoclave. After cooling at ambient temperature, result included two solid and liquid phases. Ostrich oil was stored in polyethylene terephthalate bottles without neutral gas. Scientific knowledge about the components of ostrich oil and its antioxidant activities is still limited. The hypothesis includes that low temperatures and good processes may preserve quality of ostrich oils (3, 9).

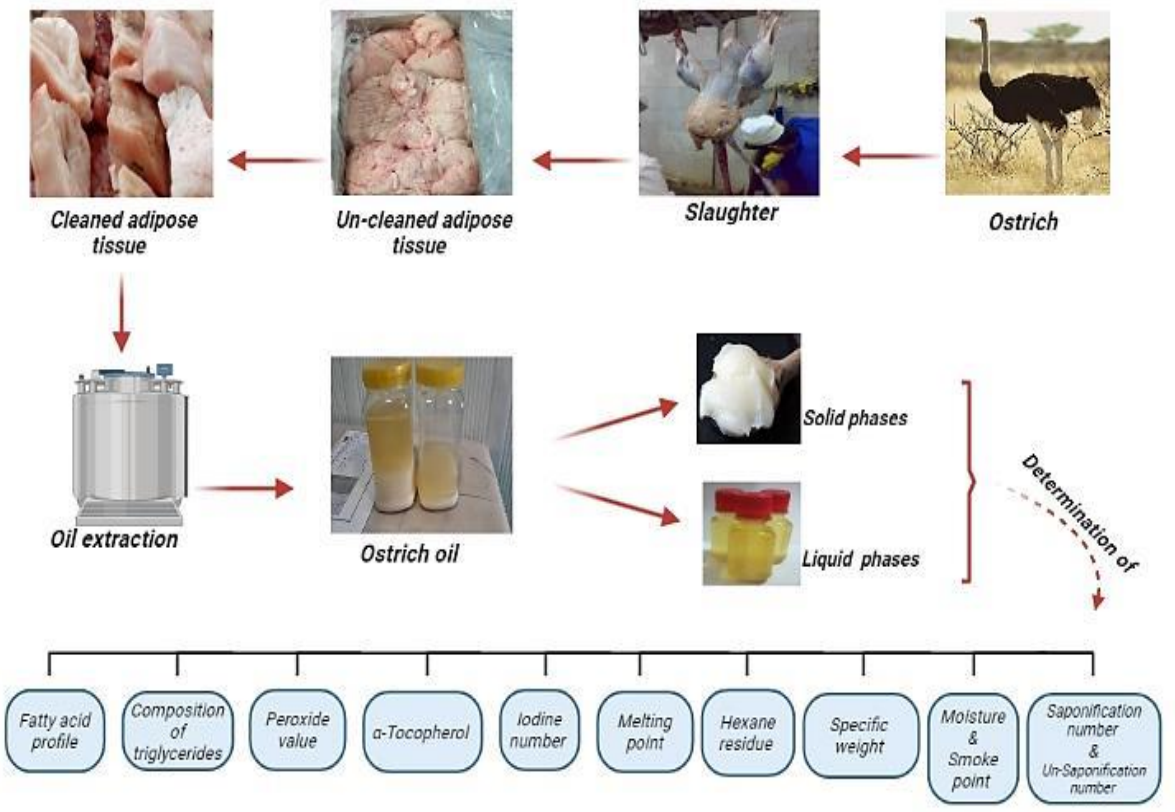

Figure 1. Preparations and experiments

[DOI: 10.61882/nfsr.12.3.41]

Assessment of fatty acid profiles

Types of FAs in samples were assessed using capillary gas chromatography (GC) and methyl esters of FAs based on (10, 11) linked to vegetable and animal oils and fats. In this method, gas chromatography-flame ionization detector (GC-FID) was analyzed using gas model of N6890.

Composition of triglycerides

Composition of oil triglycerides was assessed using GC based on the method described in (5).

Peroxide value

Quantity of peroxide is defined as milli equivalents of oxygen peroxide per 1 kg of oil. Exactly 0.1 g of potassium iodide and 30 ml of a mixed solvent [frozen acetic acid:chloroform of 2:3 (v/v)] were poured into 0.5 g of the oil sample and the mixture was thoroughly mixed. The solution was diluted with 30 ml of distilled water (DW) to prevent the loss of free iodine. Titration with standard sodium thiosulfate included a solution to achieve the equivalence point. Peroxide value (PV) in solid and liquid samples of ostrich oil was carried out based on (12–13) using iodometric method.

Other physicochemical assessments

Assessment of moisture was carried out using method of (14), quantity of α-tocopherol (vitamin E) was assessed using method of Mohamed (15), acidity level and volatile matter were estimated using method of AOAC (16) and refractive index of the samples was assessed based on the method described in (17). Stability of solid and liquid samples of ostrich oil was assessed based on (18) using rancimet method. Iodine number in solid and liquid samples of ostrich oil was carried out based on the description in AOAC (19) in (20). Assessments of saponification number as well as the melting point of solid and liquid samples of ostrich oil were carried out based on a method reported in (16, 21).

Other assessments included assessing quantity of industrial hexane residues based on the instructions of (16), smoke point using method of Akoh et al. (2017) (22) and quantity of unsaponifiable matter of solid and liquid ostrich samples based on the method described in (16, 18, 23). Concentrations (mg kg^{-1}) of heavy metals, including iron (Fe), copper (Cu), arsenic (As) and lead (Pb), were assessed based on (24). Moreover, the specific weight of samples was calculated based on (16).

Statistical analysis

All the experiments were carried out in triplicate. Means were compared using independent sample T-test ($P \leq 0.05$) and SPSS v.23 (IBM, USA).

Results

As shown in Table 1, the fattiest acid compounds in ostrich oil (liquid and solid) were respectively linked to oleic, palmitic, linoleic, palmitoleic, stearic and linolenic acids. In addition, quantity of oleic acid was 36.99 and 37.40% for liquid and solid oils, respectively. The polyunsaturated fatty acids (PUFA) of solid liquid ostrich oil included 17.21 and 17.11%, respectively. Combination of triglycerides in liquid and solid samples of ostrich oil showed that PPO (12.93%) and PLO (12.06%) included the highest quantity of triglycerides in liquid and PLO samples (13.44%), respectively, and POO (11.25%) was the highest triglyceride in the solid sample of ostrich oil. The PPS and SSO with 0.44 and 0.46% were the lowest triglycerides in liquid and solid samples of ostrich oil, respectively (Table 2). As shown in Table 3, PV in liquid ostrich oil (4.54 ±0.01 mEq. O_2 kg^{-1}) was 2.67 times higher than solid ostrich oil (1.70 ±0.02 mEq. O_2 kg^{-1}). Details of the results of various assessments can be seen in Tables 1, 2 and 3, which are discussed separately in Discussion section.

Discussion

Fatty acid composition of ostrich oil and its comparison with animal fat and vegetable oil

As shown in Table 1, the fattiest acid compounds in ostrich oil (liquid and solid) were respectively linked to oleic, palmitic, linoleic, palmitoleic, stearic and linolenic acids. Quantities of palmitic acid in fat tissues (depot fat) of cow, sheep, pig, chicken and whale have been reported as 29, 25, 30, 25 and 15%, respectively, similar to those of the present study as 28.40 and 28.80% for liquid and solid oils, showing that the quantity of palmitic acid in the stored fat of ostrich was similar to that of the stored fat of cattle and close to that of pigs (25). Similarly in the study of Amany et al. (2011), quantity of palmitic acid was listed as 48.50, 49.20, 47.50, 45.30 and 50.66% in fats of beef, buffalo, cattle, sheep and chicken, respectively (26). Quantities of oleic acid in fat tissues (depot fat) of cow, sheep, pig, chicken and whale were 41, 37, 41, 43 and 33%, respectively. In the present study, quantities of oleic acid were 36.99 and 37.40% for liquid and solid oils. This comparison showed that the quantity of oleic acid in the stored fat of ostrich was similar to the stored fat of sheep (25). In another study, quantities of oleic acid in beef, buffalo, cattle, sheep and chicken were 40, 36.80, 40.30, 41.5 and 30.30%, respectively (26). In 2019, Al-Bidhani et al. investigated the chemical contents and physicochemical characteristics of local ostrich fat. They showed that the most FAs included oleic, palmitic, arachidonic and erucic acids, respectively, in contrast to those of the current study except for oleic and palmitic acids (9). According to the World Health Organization (WHO), diets high in fats (especially saturated fats) can increase the risk of coronary heart disease.

[DOI: 10.61882/nfsr.12.3.41]

Table 1. Fatty acid contents of ostrich oils

Row	Parameter	Unit	liquid oil	Solid oil
1	C_{12}:0	Percent	0.05	0.04
2	C_{14}: 0	Percent	0.77	0.61
3	C_{14}: 1	Percent	0.14	0.06
4	C_{16}: 1	Percent	8.19	6.97
5	C_{16}: 0	Percent	28.40	28.88
6	C_{17}: 0	Percent	0.16	0.12
7	C_{18}: 0	Percent	6.29	7.08
8	C_{17}: 1	Percent	0.15	0.12
9	C_{18}: 1	Percent	36.99	37.40
10	C_{18}: 2	Percent	15.16	15.29
11	C_{18}: 1t	Percent	0.44	0.45
12	C_{18}: 2t	Percent	0.14	0.16
13	C_{18}: 3t	Percent	ND*	ND
14	C_{18}: 3	Percent	1.91	1.66
15	C_{20}: 0	Percent	0.05	0.05
16	C_{20}: 1	Percent	0.21	0.21
17	C_{22}: 0	Percent	ND	ND
18	C_{22}: 1	Percent	ND	ND
19	C_{24}: 0	Percent	ND	ND
Saturated fatty acids		Percent	35.72	36.78
Unsaturated fatty acids		Percent	63.33	62.92
Monounsaturated (MUFA)		Percent	46.12	45.21
Poly unsaturated fatty acids(PUFA)		Percent	17.21	17.11
Poly unsaturated fatty acids(PUFA)/Saturated fatty acids(SFA)		Percent	0.48	0.43
Desirable fatty acids(DFA**)			68.32	68.79

*ND: Non detected
**DFA - desirable fatty acids (total unsaturated + stearic acid)

Table 2. Triglyceride contents of ostrich oils

Row	Unit	Parameter	liquid oil	Solid oil
1	Percent	PPP	4.73	3.41
2	Percent	PPS	0.44	1.36
3	Percent	PPO	12.93	10.90
4	Percent	MOO	2.37	3.12
5	Percent	PPoO	10.00	9.35
6	Percent	PLP	4.57	2.17
7	Percent	PLPo	1.03	0.59
8	Percent	MLO	3.23	2.05
9	Percent	PSO	3.99	3.89
10	Percent	POO	11.62	11.25
11	Percent	PLS	5.78	6.38
12	Percent	PoOO	2.56	1.55
13	Percent	PLO	12.06	13.44
14	Percent	PoLO	0.83	0.97
15	Percent	PLL	3.47	4.74
16	Percent	SSO	0.55	0.46
17	Percent	SOO	2.22	1.94
18	Percent	OOO	5.14	5.32
19	Percent	SLO	2.36	2.66
20	Percent	OOL	5.03	6.76
21	Percent	OLL	2.22	2.69

[DOI: 10.61882/nfsr.12.3.41]

Table 3. Physicochemical characteristics of ostrich oilS

Row	Parameter	Unit	liquid oil	Solid oil	Permissible limits of edible animal oils*
1	Moisture	Percent	0.08±0.01[a]	0.05± 0.01[b]	
2	Volatile matter	Percent	0.1±0.0[a]	0.16± 0.01[b]	
3	Peroxide value	mEq O_2/kg	4.54±0.01[a]	1.70±0.02[b]	≤ 10.00
4	Acid value	mg KOH/g oil	0.39±0.0[a]	0.18± 0.0[b]	2.0
5	Refractive index	-	1.4604± 0.00[a]	1.4603±0.00[a]	1.448-1.460
6	Stability	h	0.21±0.02[a]	0.27± 0.01[b]	
7	Iodine value	gl 2/100 g oil	71.97± 0.00[a]	70.75 0.00[b]	36-47
8	Saponification value	mgKOH/g oil	198.35 ± 0.00[a]	197.97 ± 0.00[a]	190-200
9	Melting point	℃	24± 0.00[a]	32.65 ± 0.2[b]	
10	Smoke point	℃	250.00± 0.00[a]	250.00± 0.00[a]	
11	Un-saponifiable matter	Percent	0.38±0.01[a]	0.31±0.00[b]	
12	Specific weight	-	0.91±0.00[a]	0.91±0.00[a]	
13	α-Tocopherol (vitamin E)	mg/kg	37±0.02[a]	37.42±0.02[a]	
14	Heavy metals	mg/kg			
	Fe		0.53±0.02[a]	0.54±0.02[a]	1.5
	Pb		ND	ND	0.1
	As		ND	ND	0.1
	Cu		ND	ND	0.4

*Codex Standard for Named Animal Fats CODEX-STAN 211 – 1999, FAO/WHO
[a, b] Values in the same row with different superscript letters differ significantly (P < 0.05).
*ND: Non detected
The data are the means of three independent experiments ± standard deviations (n = 3).

In addition, WHO states that oils rich in oleic acid should be consumed as a contribution to total daily fat intake after adequate intake of PUFAs as oleic acid intake is associated with decreased risks of cardiovascular disease (CVD) (27–28). In general, the quantity of saturated fatty acids (SFA) in liquid and solid oils of ostrich in the present study were 35.72 and 36.78% respectively and in beef, buffalo, cattle, sheep and chicken were 59.90, 61.02, 59.60, 57.7 and 64.69%, respectively (26). This showed that the animal fats included higher SFAs than those ostrich oil of the present study did. Moreover, SFAs in vegetable oil such as safflower, grape, *silybum marianum*, hemp, sunflower, wheat germ, pumpkin seed, sesame, rice bran, almond, rapeseed, peanut, olive and coconut oils were 9.3, 10.4, 15.1, 9.2, 9.4, 18.2, 19.6, 16.9, 22.5, 9.3, 6.3, 10.7, 19.4 and 92.1%, respectively (29). The SFAs in vegetable oils (except for coconut oil) were lower than those in ostrich oil of the present study. Furthermore, quantities of monounsaturated fatty acids (MUFA) in liquid and solid oils of ostrich in this study were 46.12 and 45.21%, respectively. In beef, buffalo, cattle, sheep and chicken fats, these were 40, 38.80, 40.30 and 41.50 and 30.30%, respectively (26). The ostrich oil in the present study included higher MUFAs than those animal fats did. The MUFAs in vegetable oils such as safflower, grape, *Silybum marianum*, hemp, sunflower, wheat germ, pumpkin seed, sesame, rice bran, almond, rapeseed, peanut, olive and coconut oils were 11.6, 14.8, 20.7, 28.1, 28.3, 20.9, 26.1, 42.0, 44.0, 67.9, 72.8, 71.1, 68.2 and 6.2%, respectively (29). The MUFAs of almond, rapeseed, peanut and olive oils were higher than the MUFAs of ostrich oil. Rest of the oils included lower values, compared to ostrich oil. The quantities of linoleic acid in fat tissues (depot fat) of cattle and sheep were reported as 29 and 15%, respectively (24). Compared to the results of the present study, these were 0.40 and 0.80% for liquid and solid oils, showing that quantity of linoleic acid in the stored fats of ostriches was less than that of cattle and sheep. It is noteworthy that linolenic acid was not detected by studies on adipose tissues of cattle and sheep (26), Generally, PUFAs of solid liquid ostrich oil in the present study were 17.21 and 17.11%, respectively. In beef, buffalo, cattle, sheep and chicken, this was 0.10, 0.18, 0.15, 1.02 and 0.33%, respectively (26). Ostrich oil of this study included higher PUFAs than those animal fats did. Moreover, PUFAs in vegetable oils such as safflower, grape, *S. marianum*, hemp, sunflower, wheat germ, pumpkin seed, sesame, rice bran, almond, rapeseed, peanut, olive and coconut oils included 79.1, 74.9, 64.2, 62.8, 62.4, 61.0, 54.3, 41.2, 33.6, 22.8, 20.9, 18.2, 18.0 and 1.65, respectively (29). The ostrich oil of the present study included lower PUFAs (except coconut oil) than that vegetable oil did, almost similar to olive and peanut oils. The PUFAs are sources of omega-6 and omega-3; of which, ostrich oil of the present study included a significant quantity. Results were in contrast to animal fats, which included a small quantity of

[DOI: 10.61882/nfsr.12.3.41]

PUFAs. Recent studies have clearly shown the important effects of PUFAs on human health in preventing CVDs, coronary heart disease and cancers, inflammatory, thrombotic and autoimmune diseases, hypertension, diabetes type-2, renal diseases, rheumatoid arthritis (RA), ulcerative colitis (UC) and Crohn's diseases (CD) (30–31). The highlighted cases showed that generally the quantity of UFAs in ostrich was much higher than that to other animal fats. The UFAs in edible oil can decrease the levels of various types of cholesterol in people with hyperlipidemia, improve postprandial lipoprotein metabolism and include anticancer effects in animal models and human cell lines (32–33). To assess the nutritional quality of ostrich fat, PUFA/SFA ratio and DFA content were assessed. Stearic acid, one of the predominant SFAs, includes health-promoting benefits such as decreasing blood cholesterol (34). The quantity of DFA in the present study (68.32 and 68.79%) was lower than that published by Belichovska et al. in 2015 (70.4%) (35). Based on the health recommendations of the WHO, the ratio of PUFA to SFA in the human diets should be more than 0.4 (36). Based on Table 1, PUFA/SFA ratios of ostrich oil samples were more than 0.43, consistent with nutritional recommendations. The high content of UFAs indicated that ostrich oil included a high nutritional value. In animal fats, PUFA/SFA ratios of ostrich oil in beef, buffalo, cattle, sheep and chicken were almost 0% (26), showing that ostrich oil included a high nutritional value.

Ostrich oil triglycerides

Triglycerides are detected in plant oils and animal fats. Their characterization is important for nutritional reasons, where the quantity of unsaturation must be known, as well as for determining other characteristics of the oil such as product purity and appropriateness for deep frying (37). The findings of this study on the combination of triglycerides in liquid and solid samples of ostrich oil showed that PPO (12.93%) and PLO (12.06%) included the highest quantity of triglycerides in liquid and PLO samples (13.44%), respectively. Moreover, POO (11.25%) was the highest triglyceride in the solid sample of ostrich oil. In contrast, PPS and SSO with 0.44 and 0.46% were the lowest triglycerides in liquid and solid samples of ostrich oil, respectively (Table 2).

Physicochemical characteristics of oils

As shown in Table 3, all the values of physicochemical characteristics except the iodine value included the permissible limits set by the Codex standard for animal fats of CODEX STAN 211-1999, Food and Agriculture Organization (FAO)/WHO.

Peroxide value

The VP in liquid ostrich oil (4.54 ±0.01 mEq. O_2 kg^{-1}) was 2.67 times higher than VP in solid ostrich oil (1.70 ±0.02 mEq. O_2 kg^{-1}). Higher peroxide content in liquid ostrich oil indicated partial lipid oxidation. This showed that ostrich liquid oil was more sensitive to oxidation than that ostrich jam oil was. Lipid oxidation leads to the production of unstable hydroperoxides, which further decompose into secondary oxidation products including alcohols, aldehydes, ketones, acids and hydrocarbons (38). The PV for sesame, sunflower and rapeseed oils in the cold-pressed and industrially refined preparation methods was 10 and 2 mEq. O_2 kg^{-1}, respectively; however, PV standard was 5 mEq. O_2 kg^{-1}. Comparing PV of ostrich oil with those of vegetable oils, it was clear that the PV in solid and liquid samples was acceptable even without industrial refining (39).

Acid value

The acid value is one of the important indicators of edible oil safety. Freshness and purity of the oil can be assessed by its low acid values. The nutritional value of edible oil decreases with increasing acid value and long-term consumption of edible oil with high acid value is harmful to human health (40). The acid value of the ostrich oil samples was less than the international standards (Table 2). However, acid value of the oil sample from liquid ostrich oil (0.39 ±0.01 mg KOH g^{-1} oil) was higher ($P < 0.05$) than that of solid ostrich oil (0.18 ±0.00 mg KOH g^{-1} oil). This showed that the liquid ostrich oil sample included a higher free fatty acid (FFA) content than that the solid oil sample did. The FFAs could accelerate oxidation of oils and hence acid value included a major effect on the stability and flavor quality of oils. It could be concluded that a higher extraction temperature produced liquid ostrich oil with higher acid values.

Tocopherol

Tocopherols are the important components of non-saponifiable ingredients of edible oils that include antioxidant activity and deactivate free radicals. As the vitamin E, they affect human health (41). In the present study, ostrich oil (liquid and solid oils) contains α-tocopherol, which all vitamin E isoforms destroy reactive oxygen species (ROS) due to the presence of phenolic hydrogen in their chromanol ring (42). All vitamin E isoforms include an anti-inflammatory effect by inhibiting various inflammatory mediators. The isoforms inhibit cyclooxygenase-2 mediated production of prostaglandin E2, as well as 5-lipooxygenase mediated production of leukotrienes of LTB4, LTC4 and LTD4 (43). The α-tocopherol scavenges peroxyl radicals during the propagation of lipid peroxidation and is termed a chain-breaking antioxidant because it prevents the chain reaction of lipid peroxidation. There are several factors when comparing oils, one of which is the quantity of antioxidants such as α-tocopherol. Relatively, ostrich oil was richer than beef oil, which contained averagely 23–28 mg kg^{-1} α-tocopherol (44).

[DOI: 10.61882/nfsr.12.3.41]

Melting point

In the present study, the melting points of liquid and solid ostrich oils were 24 and 32 °C, respectively. The melting point of ostrich oil was lower than that of other animal fats. For example, the melting point of beef, buffalo, cattle, sheep and chicken fats were 45.10, 47, 46.50, 48.30 and 48.20 °C, respectively (26, 45), much higher than ostrich oil. This showed that these data were similar, while ostrich oil was semi-solid at room temperature (RT), compared to other fats. In other words, the melting point was higher in animal fats such as cow and sheep tallows due to the high quantity of SFAs, including stearic acid. In ostrich fat, the dominant FA was oleic acid.

Refractive index

The refractive index of oils increases with the increase in the degree of unsaturation and length of the FA chain. Various types of oils showed various refractive indices, while values of the similar types were close. The refractive indices of the liquid and solid ostrich oil samples were completely similar based on the permissible limit, which indicated the purity and authenticity of the two oil samples. The refractive index of animal fats was lower than that of vegetable oils and with the increasing number of double bonds, the refractive index of oils increased, helping identify oils and fats. This suggested that the refractive index could be adopted in the identification of oils and plays a critical role in the quality control of oils. Based on the standard, the refractive index of the samples at 40 °C showed a similar number. Based on the results, the refractive indices for liquid and solid ostrich oils were 1.4603 and 1.4604, respectively, similar to goose fat (1.456–1.462) (46). By comparing the refractive index of edible tallow, sheep and camel hump oils, respectively reported at 1.460, 1.456 and 1.45; it was detected that the refractive index of ostrich oil was close to the stated edible oils (47).

Iodine value

In the present study, the relative values for liquid and solid ostrich oils were 71.97 and 70.75 gI_2, respectively, while animal fats such as goose fat, edible tallow and beef, buffalo, cattle, sheep and chicken fats were 59, 50, 60, 55, 58, 53 and 56 gI_2, respectively. This showed that the UFAs in ostrich oil were higher than UFAs in animal fats (46, 58). However, the values of vegetable oils such as those of canola, coconut, corn, cottonseed, linseed, palm, peanut, rapeseed, safflower, soybean and sunflower were188193,6–11,103–128,99–119,177, 50–55, 80–106, 94–120, 135–150, 189–195 and 188–194, respectively (48), which (except coconut oil) were higher than those of ostrich oil. The iodine index in this study was similar with that in a study of Sells and Franken (1996) as well as a study of Jamalipour et al. (2013) on ostrich oil. The iodine index reflects the extent; to which, the oil contains PUFAs and describes its susceptibility to spoilage and oxidation (4, 47). The content of fat-soluble vitamins cannot be synthesized in ostrich fat and is achieved through plant nutrition. Therefore, the content of these vitamins depends on the quality of ostrich nutrition. Al-Bidhani et al. (2019) in a study on ostrich oil reported the quantity of vitamin E or α-tocopherol as 91.30 mg ml^{-1} (9).

Smoke point

The smoke point is the oil resistance to heat. The higher the smoke point of an oil, the more resistant it is to heat and the more appropriate it is for deep frying. Various oils include various smoke points, which make oils further appropriate for frying. For example, sunflower oil is one of the vegetable oils that includes a high smoke point and is appropriate for frying foods. In contrast, olive oil includes a lower smoke point than that other oils does and is not hence appropriate for deep frying. The smoke point is the temperature; at which, a fat or oil produces continuous smoke. This is a useful indicator of its appropriateness for frying and 200 °C is often set by regulations as the minimum temperature (49). In the present study, the smoke points of liquid and solid camel oil were 250 and 250 °C, respectively, with no significant differences ($P > 0.05$). Oils with a smoke point greater than 190 °C can be used for frying foods. Comparing the smoke point of ostrich oil with other edible oils, the smoke point of ostrich oil is higher. The smoke point of an oil is the temperature; at which, the oil begins to decompose, smoke and burn, producing a carcinogen called acrolein (converting glycerol to acrolein (12, 50–51) if heated at temperatures greater than that temperature. The higher the smoke point of oil, the lower the quantity of FFAs in that oil. The smoke point of corn oil was 236, that of olive oil was 190, the smoke point of soybean oil was 241 and the value of sunflower oil was 264 (52–53).

Saponification value

Saponification value depends on the length of fatty acyl chains of triglycerides. A low saponification value indicates long-chain fatty acids (LCFA) in the glycerol backbone of a sample. In contrast, a high saponification value indicates triacylglycerols with shorter FA chains. As a result, saponification value becomes an easy approach to assess the FA chain length of certain fats and oils. For example, most common oils and fats of vegetable or animal origin (e.g. sunflower, soybean, canola, lard, beef tallow and chicken fats) contain approximately similar LCFAs (C18 and C16) with similar saponification values (168–196 mg KOH g^{-1} oil) (54). Vegetable oils such as coconut and palm-kernel oils contain large quantities of lauric and myristic acids, whose saponification value is significantly higher (235–260 mg KOH g^{-1} oil) (55–56). Milk fat differs significantly from other fats and oils in its FA profile, including quantities of short and medium-chain fatty acids

[DOI: 10.61882/nfsr.12.3.41]

(SCFA and MCFA respectively), which is subsequently reflected in its high saponification value (213–227 mg KOH g^{-1} fat) (57–58). Therefore, saponification value may be useful in detecting adulterations of dairy products with cheaper fats and oils, as the addition of a C18-rich oil/fat to a dairy product results in a decreased exchange rate. The Saponification number provides useful information on the purity of oils and can be used to detect frauds. A specific saponification number is reported for oils. Results of this study showed that the saponification number of ostrich oil was close to the saponification number of corn (187–195), palm (190–202) and safflower (186–198) oils (24, 59).

Heavy metal contents

Assessment of heavy metals is important because of their roles in increasing oxidation of oils and their processing and storage as well as toxicities (24). In Table 1, contents of Fe, Cu, As and Pb in the two ostrich oils were reported. The Cu, As and Pb samples were not detected and the iron concentrations in liquid and solid ostrich oils were 0.53 and 0.54 mg kg^{-1}, respectively, still lower than the limit of edible animal oils (1.5 mg kg^{-1}) of the Codex standard (CODEX-STAN 211—1999). Results could indicate the optimal quality of oils for this parameter. In the present study, unlike the previous studies that investigated various characteristics of ostrich oil, the authors tried to investigate edible possibility of ostrich oil, compared with other oils by separately examining the two phases of ostrich oil (liquid and solid). Based on the results of this study, ostrich oil could be used for use in food industries due to its solid-liquid characteristics and appropriate quantities of tocopherol, which could protect the oil against oxidation based on the standards of heavy metals and contents of UFAs.

Conclusion

In the present study unlike the previous studies that investigated various characteristics of ostrich oil, it was tried to investigate edible possibility of ostrich oil, compared with other oils by separately assessing the two phases of ostrich oil (liquid and solid). Based on the results from this study, ostrich oil can be used for use in the food industry due to its solid-liquid characteristics, appropriate quantity of α-tocopherol that can protect the oil against oxidation and optimal level and based on the standards for heavy metals and contents of UFAs. For example, a high smoke point is needed in production of frying products, which is a characteristic of ostrich oil. Additionally, good α-tocopherol content in this oil can make it appropriate for use in high-fat products.

Authors' Contribution

Asghar Azizian collected the samples and carried out the experiments, Alireza Bahonar, Mojtaba Ayaz and Norallah Nikkhah carried out analysis interpretation of the data, Alireza Bahonar and Asghar Azizian wrote and revised the manuscript.

Financial disclosure

The authors declare no known competing financial interests or personal relationships that could affect this study.

Funding/Support

This project has been carried out with supports of the Science and Technology Park of the University of Tehran (in form of call for growth).

Ethics statement

The authors of this study declare that all steps in this study, including killing of ostriches in an industrial slaughterhouse, were carried out in accordance with the principles of the Ethics Committee of the Iranian Veterinary Organization.

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