Original scientific paper
UDC 664.3:577.115.3

FATTY ACID COMPOSITION OF EDIBLE OILS AND FATS

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Abstract

The content of fatty acids as well as the ratio between unsaturated and saturated fatty acids is important parameter for determination of nutritional value of certain oil. Therefore the newest trend in food processing industry is notifying the composition of edible oils and other food commodities for the content of each individual fatty acid.

The main objective of this work was to identify the fatty acid composition of several vegetable oils and fats. Eleven vegetable oils and fats (n=121) were analyzed for its fatty acid composition by gas chromatography (GC-FID) on HP-FFAP and SPB^{TM-1} column, respectively. Among the evaluated oils the higher contents of saturated fatty acids were found in palm kernel oil (76.0% ± 1.95) and coconut fat (90.5% ± 2.95) with predominant presence of lauiric acid ($C_{12:0}$) and myristic acid ($C_{14:0}$) compared to content of total saturated fatty acids in linseed oil (9.65% ±1.05), sunflower seed oil (8.8% ± 0.8) and safflower oil (7.2% ± 0.73). The result showed that the sunflower oil, safflower oil and linseed oil contain the highest percentage of long chain mono and polyunsaturated fatty acids: oleic acid ($C_{18:1}$), linoleic acid ($C_{18:2}$) and linolenic acid ($C_{18:3}$). Two varieties of canola oil, high linolenic (44.0% ± 2.02, n=21) and high oleic acid (59.5% ± 1.907, n=20) were found. The highest P/S index (Polyunsaturated/Saturated index) was found for safflower oil (10.55) and the lowest P/S indexes were found for palm kernel oil (0.016) and coconut fat (0.005).

The fatty acid composition of safflower and sunflower oil contains a healthy mixture of all the types of saturated and unsaturated fatty acid. The value of P/S index which is associated to the impact in the human health is also high for safflower (10.55) and sunflower oil (6.76), which makes them the most suitable edible oils for mass consumption.

***Key words**: Fatty acid, Lauric acid, Myristic acid, Oleic acid, Linoleic acid, Linolenic acid, P/S index, Gas chromatography.*

1. Introduction

Edible oils and fats are biological mixtures of plant origin consisting of ester mixtures derived from glycerol with chain of fatty acids [1]. Both the physical and the chemical characteristics of oils and fats are greatly influenced by the kind and proportion of the fatty acids on the triacylglycerol [2, 3]. Fatty acids can be classified in classes as saturated, mono-unsaturated (MUFA) and polyunsaturated (PUFA) fatty acids. On the other hand, the unsaturated ones are classified into series known as omega, being ω-9 considered nonessential for humans, and the ω-3 and ω–6 as essential fatty acids, because the latter ones cannot be synthesized by mammals; therefore, they are obtained from diet [4, 5]. The predominant fatty acids present in vegetable oils and fats are saturated and unsaturated compounds with straight aliphatic chains. An even number of carbon atoms, from 16 to 18, with a single carboxyl group, is the most common. A number of minor fatty acids may be present in same vegetable sources, including a small amount of branched chain, cyclic and odd number straight chain acids [6, 7]. An important feature common to most plant origin oils and fats is the high percentage of unsaturated fatty acids in the triacylglycerols. In general, higher degree of unsaturation of fatty acids in vegetable oils, the more susceptible they are to oxidative deterioration [3, 7, and 8]. Therefore, it is essential to know the composition of fatty acids of an oil or fat, to identify their characteristics and to determine the possible adulteration, as well as to know the stability and physical – chemical properties of these products [3, 9]. The short chain fatty acids are of lower melting point and are more soluble in water. Whereas, the longer chain fatty acids have higher melting points. Unsaturated fatty acids have a lower melting point compared to saturated fatty acids of similar chain length [10]. Vegetable oils are one of the major components of human diets, comprising as much as 25% of average

caloric intake. Vegetable oils play important functional and sensory roles in food products and they act as carriers of fat-soluble vitamins (A, D, E, and K). They also provide an essential linoleic and linolenic acid, responsible for growth [11].

The rate of unsaturated to saturated fatty acids in edible oils and fats is very important for human nutrition. While high levels of saturated fatty acids is desirable to increase oil stability, on the other hand nutritionally they become undesirable, because high levels of saturated fatty acids are frequently considered to have influence in increasing the concentration of low density lipoproteins (LDL), affecting the ratio of LDL to HDL (high density lipoproteins), promoting clothing and vascular smooth muscle proliferation [12, 13]. Diet with increasing intake of linoleic and linolenic acids increase HDL-cholesterol and decreases LDL-cholesterol, while higher intake of oleic acid decreases LDL-cholesterol, but does not affect HDL cholesterol levels [14].

The main objective of this work was to identify the fatty acid composition of several vegetables oils and fats obtained from the market, in order to improve understanding of the oil quality, stability and applicability for human nutrition.

2. Materials and Methods

2.1 Materials

Samples of twelve different varieties of vegetable oils and fats as: coconut fat (7 samples), corn oil (10 samples), cottonseed fat (6 samples), linseed oil (8 samples), palm kernel fat (7 samples), olive oil (10 samples), soybean oil (5 samples), sunflower seed oil (15 samples), safflower oil (5 samples), canola oil variety 1 (20 samples); canola oil variety 2 (21 samples) and peanut oil (7 samples) were collected from the local market during the period between May 2012 to April 2013.

2.2 Methods

2.2.1 Preparation of fatty acid methyl esters (FAMEs)

Fatty acid (FA) composition of the oils and fats was determined as their corresponding methyl esters. Preparation of FAMEs was carried out according to the modified ISO method [15]. 0.1 - 0.2 g of certain oil was dissolved in 10 mL 0.2 mol/L H_2SO_4 prepared in anhydrous methanol. Esterification was performed by refluxing for 30 minutes at 100 ^{0}C in tightly sealed Pyrex tubes. After cooling at room temperature, 10 mL of petroleum ether (40 - 60) was added followed by 10 mL of deionized water, mixed gently and allowed to settle until the upper petroleum ether layer becomes clear. The distinct upper layer of methyl esters in petroleum ether was separated carefully in a capped vial and used for analysis. 2 µL of the petroleum ether aliquots were injected into the chromatographic column and peaks were recorded for their respective retention times and areas by the data processor unit of the GC. Identification of each individual fatty acid methyl ester was achieved by comparison with authentic reference standards. All solvents and standards were of analytical grade (Merck, Fluka).

2.2.2 Chromatography

HP model 5890 series II (plus) gas chromatograph equipped with an HP automatic liquid sampler and a flame-ionization detector (FID) was used either with a nonpolar fused silica capillary column (30 m x 0.32 mm id. x 1 µm film thickness) coated with 100% poly(dimethylsiloxane), commercially available as SPB™-1 obtained from Supelco (USA). The carrier gas (nitrogen) flow rate was 1.5 mL·min^{-1} and the split ratio was 1:10. The injection port was maintained at 250 ^{0}C and the FID at 280 ^{0}C. Oven temperature was set at 200 ^{0}C (1 minute) increasing for 5 ^{0}C ·min^{-1}. The final oven temperature was maintained at 250 ^{0}C (20 minutes).

For confirmation of identified and determined FAMEs in oils and fats, a polyethylene glycol TPA modified polar column commercially available as HP-FFAP (25 m x 0.32 mm id x 0.52 µm) was used with the same HP model 5890 series II (plus) gas chromatograph. The carrier gas (nitrogen) flow rate was 1.5 mL·min^{-1} and the split ratio was 1:10. The injection port was maintained at 230 ^{0}C and the FID at 260 ^{0}C. Oven temperature was set at 180 ^{0}C increasing for 2 ^{0}C ·min^{-1}. The final oven temperature was maintained at 230 ^{0}C (4 minutes).

3. Results and Discussion

A total of 121 samples of vegetable oils and fats samples collected from the local markets were analyzed on the composition of fatty acids using gas chromatographic method. Types and number of collected samples were: fifteen samples were sunflower; twelve samples were canola oil; ten samples were corn oil and olive oil; eight samples were linseed oil, seven samples were coconut fat, palm kernel fat and peanut oil; six samples were cottonseed fat and five samples were soybean oil and safflower oil. The content of following saturated and unsaturated fatty acids was tested in the samples : caproic acid ($C_{6::0}$), caprylic acid ($C_{8::0}$), capric acid ($C_{10::0}$), lauric acid ($C_{12::0}$), myristic acid ($C_{14::0}$), palmitic acid ($C_{16:0}$), stearic acid ($C_{18::0}$), arachidic acid ($C_{20:0}$), behenic acid ($C_{22::0}$) , lignoceric acid ($C_{24::0}$), oleic acid ($C_{18::1}$), linoleic ($C_{18::2}$) and linolenic acid ($C_{18:3}$). The fatty acid percent composition of tested oils and fats are shown

in Table 1 and Table 2, respectively. The mean of total saturated fatty acid (SFA), monounsaturated fatty acids (MFA), polyunsaturated fatty acids (PUFA) and the values of polyunsaturated/saturated indexes (P/S) are shown in Table 3.

Table 1. Saturated fatty acid composition of different types of vegetable oils and fats (% w/w)

Type of Oil/Fat	Mean ± SD							
	$C_{6:0}$ (%)	$C_{8:0}$ (%)	$C_{10:0}$ (%)	$C_{12:0}$ (%)	$C_{14:0}$ (%)	$C_{16:0}$ (%)	$C_{18:0}$ (%)	$C_{20:0}$ (%)
Coconut (n=7)	0.04±0.2	7±2.0	8±2.0	48 ±4	16±3.0	9.2±1.5	2±1.0	0.25±0.2
Corn (n =10)	-	4±0.8	7±1.2	-	0.6±0.4	10±2	3.5±1.5	-
Cottonseed (n=6)	-	-	-	-	0.4±0.2	20±2.5	2±0.6	-
Linseed (n=8)	-	-	-	-	-	5.5±1.5	3.5±1.2	0.65±0.3
Palm Kernel (n=7)	-	4±1	5±2	41 ±5	16±2	8±1.0	2±0.8	-
Olive (n=10)	-	-	-	-	0.65±0.2	11.5±4	2±0.5	0.22±0.12
Soybean (n=5)	-	-	-	-	0.5±0.2	9±2	4±1.5	-
Sunflower seed (n=15)	-	-	-	-	-	3.7±1.5	2±0.8	2.3±1.2
Peanut (n=7)	-	-	-	-	-	7.5±1.5	4.5±1.8	3±1.2
Safflower (n=5)	-	-	-	-	0.5±0.2	4.0±1.8	2.5±1.5	0.2±0.1
Canola type 1 (n=20)	-	-	-	-	-	5.2±0.6	4.4±1.4	-
Canola type 2 (n=21)	-	-	-	-	-	10.5±2.5	6.9±1.6	-

Table 2. Unsaturated fatty acid composition of different types of vegetable oils and fats (% w/w)

Type of Oil/Fat	Mean ± SD		
	$C_{18:1}$ (%)	$C_{18:2}$ (%)	$C_{18:3}$ (%)
Coconut (n=7)	8.8 ± 0.85	0.5 ± 0.2	-
Corn (n =10)	26.8 ± 1.2	48 ± 4.5	-
Cottonseed (n=6)	35.4 ± 2.4	42 ± 4.8	-
Linseed (n=8)	22.1 ± 1.5	20.5 ± 1.5	47.5 ± 5.6
Palm Kernel (n=7)	22.5 ± 2.2	1.25 ± 0.55	-
Olive (n=10)	78.4 ± 4.3	7.0 ± 3.3	-
Soybean (n=5)	28.5 ± 1.2	49.5 ± 6.5	8 ± 3.4
Sunflower seed (n=15)	31.5 ± 4.5	59.5 ± 7.5	-
Peanut (n=7)	58.5 ± 5.8	20 ± 2.7	-
Safflower (n=5)	16.6 ± 4.5	76 ± 3	
Canola variety 1 (n=20)	59.5 ± 1.907	18.8 ± 3.5	11.9 ± 1.1
Canola variety 2 (n=21)	23.2 ± 2.9	15.2 ± 3.6	44 ± 2.02

Table 3. The content of SFA, MUFA, PUFA (% w/w) and the values of P/S indexes in different types of vegetable oils and fats

Type of Oil/Fat	Mean ± SD			P/S index
	SFA (%)	MUFA (%)	PUFA (%)	
Coconut (n=7)	90.5 ± 2.95	8.8 ± 0.85	0.5 ± 0.02	0.005
Corn (n =10)	25.1 ± 1.8	26.8 ± 1.2	48 ± 4.5	1.91
Cottonseed (n=6)	22.4 ± 1.22	35.4 ± 2.4	42 ± 4.8	1.87
Linseed (n=8)	9.65 ± 1.05	22.1 ± 1.5	68 ± 2.9	7.05
Palm Kernel (n=7)	76 ± 1.95	22.5 ± 2.2	1.25 ± 0.55	0.016
Olive (n=10)	14.35 ± 1.9	78.4 ± 4.3	7.0 ± 3.3	0.49
Soybean (n=5)	13.5 ± 0.93	28.5 ± 1.2	57.5 ± 2.2	4.26
Sunflower seed (n=15)	8.8 ± 0.8	31.5 ± 4.5	59.5 ± 7.5	6.76
Peanut (n=7)	19.2 ± 0.37	58.5 ± 5.8	20 ± 2.7	1.04
Safflower (n=5)	7.2 ± 0.73	16.6 ± 4.5	76 ± 3	10.55
Canola variety 1 (n=20)	9.6 ± 0.56	59.5 ± 1.907	30.7 ± 1.7	3.2
Canola variety 2 (n=21)	17.4 ± 0.67	23.2 ± 2.9	59.2 ± 1.1	3.4

The results from this study, showed that the percentage of the total SFA ranged from 7.2% ± 0.73 for safflower oil to 90.5% ± 2.95 for coconut fat, with the predominant presence of lauiric acid ($C_{12:0}$) and myristic acid ($C_{14:0}$). This is following the general rule, where the major FA present in the vegetable oil or fat showed an even number of carbon atoms [6].

Except for palm kernel oil and coconut fats, palmitic acid ($C_{16:0}$) was the major saturated FA for all oils, followed by stearic acid ($C_{18:0}$). These findings were similar with those of Zambiazi *et al.* [16]. The content of myristic acid ($C_{14:0}$) in corn oil, cottonseed oil, olive oil, soybean oil and safflower oil was low, ranging from 0.40% ± 0.2 for cottonseed oil to 0.65% ± 0.2 for olive oil. The presence of behenic acid ($C_{22:0}$) was found only in the samples of sunflower seed oil (0.8% ± 0.2) and peanut oil (2.2% ± 1.2), and the presence of lignoceric acid ($C_{24:0}$) was found only in the tested samples of peanut oil (2% ± 0.8). Arachidic acid ($C_{20:0}$) was found in samples of coconut fat, linseed oil, olive oil, sunflower seed oil, peanut oil and safflower oil, within the range from 0.20% ± 0.1 for safflower oil to 3.0% ± 1.2 for peanut oil.

Peanut oil showed the highest long chain SFA content, comprising 7.2% of arachidic ($C_{20:0}$), behenic ($C_{22:0}$) and lignoceric FA ($C_{24:0}$). These findings are very close to the results presented by Zambiazi *et al.* [16], where total content of these three SFA was found to be 6.18%.

Coconut fat and palm kernel oil showed different pattern of SFA composition in comparison with the rest of the tested oils. Lauric acid ($C_{12:0}$) was the predominant fatty acid in palm kernel oil (41% ± 5) and coconut fat (48% ± 4). Besides lauric acid another short chain SFA as caprylic acid ($C_{8::0}$), capric acid ($C_{10::0}$), myristic acid ($C_{14::0}$), palmitic acid ($C_{16:0}$) and stearic acid ($C_{18:0}$) were also present in both oils. Because of a high content of short chain FA these oils are used in chemical industry for manufacturing of detergents and soaps [16].

All samples presented total SFA content less than one fourth of the total FA content (saturated and unsaturated FA), except coconut and palm kernel fat. The content of total SFA in corn oil was found to be approximately one fourth of total FA content. It is known that the excessive consumption of SFA is related to the increase of the plasmatic cholesterol and the obesity [5]. On the other hand, the consumption of PUFA and MUFA has been recommended to improve the lipid profile in relation to the saturated SFA. Yu-Poth *et al*. indicate that the rich diets in PUFA may provoke an increase in the LDL - cholesterol oxidation and the reduction of the HDL -cholesterol levels [17]. There is a tendency in increasing the recommendations of MUFA consumption, that seems not to affect the HDL levels, and also it may reduce the LDL and triacylglycerols blood levels, that make it more effective in prevention of hearth diseases.

Corn oil showed the similar content of PUFA (48.0% ± 4.5) as soybean oil (57.5% ± 2.2), which was in accordance with findings of Lawton *et al*. [14].

Sunflower seed oil also showed high PUFA content (59.5% ± 7.5) with the predominant presence of linoleic acid ($C_{18:2}$), which makes this oil suitable for use as a salad oil [18]. In all tested samples of sunflower oil, the presence of linolenic acid ($C_{18:3}$) was not found. According to the investigation of Zambiazi *et al. [*16] and Chowdhury *et al.* [19], the content of linolenic acid ($C_{18:3}$) in sunflower seed oil was found to be within the range from 0.12 – 0.45%.

Olive oil is nutritionally considered one of the best salad vegetable oil due to the highest MUFA content (75% -77 %), which is mainly due to the predominant presence of oleic acid ($C_{18:1}$). Our investigations of FA composition of olive oils showed that the content of MUFA in olive oils was 78.4% ± 4.3.

The highest content of total unsaturated FA was found for safflower (92.6% ± 1.06) and sunflower oil (91% ± 2.12), followed by canola oil - variety 1 (90.2% ± 0.45) and linseed oil (90.1% ± 0.99). The lowest content of unsaturated FA was found for coconut fat (4.65% ± 0.15). These findings were in line with the literature data [19].

Two varieties of canola oil were tested on the fatty acid composition: variety 1, with the high content of oleic acid (59.5% ± 1.907) and variety 2, with the high content of linolenic acid (44% ± 2). Soybean oil and the canola oil (variety 1) showed similar presence of linolenic acid, ranging from 8% ± 3.4 for soybean oil to 11.9% ± 1.1 for canola oil. This is considered adequate for giving ω - 3 source, and allied to the other FA content, relatively good oil stability at room temperature [9]. Even with similar linolenic acid content canola oil (variety 1) showed different pattern from soybean, which is due to lower soybean oil content in MUFA (28.5% ± 1.2), and higher content in PUFA (57.5% ± 2.2). The lower content of SFA and higher content of MUFA makes canola oil nutritionally more adequate than soybean oil for salad and cooking purposes [13].

Linseed oil was the richest one in ω - 3-fatty acid with 47.5% ± 5.6 of linolenic acid. Linolenic acid is a ω - 3 PUFA that plays an important role in the regulation of biological functions, prevention and treatment of a great number of human diseases, such as hearth and inflammatory diseases [20]. But, as the amount of PUFA content increases, an oxidation reaction of oil is more likely to occur. The higher content of linolenic acid makes linseed oil unsuitable for human consumption [21].

Oleic acid ($C_{18:1}$) was found to be predominant unsaturated FA in coconut fat (8.8% ± 0.85) and palm kernel fat (22.5% ± 2.2). Linoleic acid ($C_{18: 2}$) was the predominant unsaturated FA (42% ± 4.8) in cottonseed oil, which also contains high level of SFA (22.4% ± 1.22). These findings were in correlation of the literature data [16].

The relationship between saturated and polyunsaturated FA content is expressed as P/S index. This value is an important parameter for determination of nutritional value of certain oil. Oils and fats with higher value of P/S index than 1 are considered to have nutritional value. Several studies indicate that higher value of P/S index means a smaller deposition of lipids in the body [14]. The values of P/S indexes of tested oils and fats are shown in Table III. The higher value for P/S index was found for safflower oil (10.55) and the lowest for palm kernel oil (0.016) and coconut fat (0.005). These results are in line with the data obtained from the literature [16, 18].

4. Conclusions

- Canola oil (variety 2) and linseed oil differed from the others by presenting appreciable amount of linolenic acid ($C_{18:3}$) ranged from 44% ± 2.02 for canola oil to 47.5% ± 5.6 for linseed oil. Linolenic acid is a ω - 3 PUFA that plays an important role in the regulation of biological functions. But, as the amount of PUFA content increases, an oxidation reaction of oil is more likely to occur. The higher content of linolenic acid makes linseed oil unsuitable for human consumption

- Canola oil (variety 1) and olive oil showed the highest values of MUFA (59.5% ± 1.907 for canola oil variety 1 and 78.4% ± 4.3 for olive oil), with the predominant presence of oleic acid Because of the high content of oleic acid, olive oil is nutritionally considered as one of the best salad vegetable oils.
- Peanut, cotton and corn oils, showed higher content of unsaturated FA (more than 75%) than saturated ones, which is mainly due to the distribution between oleic ($C_{18:1}$) and linoleic acid ($C_{18:2}$).
- The fatty acid composition of safflower and sunflower oil contains a healthy mixture of all the types of saturated and unsaturated fatty acid In consideration of total percentage of unsaturated FA (MUFA + PUFA), sunflower oil appears superior. On the other hand in respect of total percentage of essential FA (linoleic and linolenic), soybean oil is superior. But on overall consideration, sunflower oil with the highest percentage of MUFA and PUFA appeared to be suitable for mass consumption. The value of P/S index which is associated to the impact in the human health is also high for safflower (10.55) and sunflower oil (6.76), which makes them the most suitable edible oils for mass consumption.

5. References

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