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COMPARISON OF FATTY ACID COMPOSITION OF VARIOUS TYPES OF EDIBLE OILS

S. IVANOVA*, G. MARINOVA and V. BATCHVAROV
Agricultural Academy, Institute of Cryobiology and Food Technologies, BG-1407, Sofia, Bulgaria

Abstract

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In recent years, there is increasing interest in fatty acid composition and the effects of oils on human health. The fish and krill oils are rich source of omega-3 fatty acids, while the plant oils (walnut, sunflower, pumpkin, olive) are a good source of linoleic acid. In the flaxseed oil the main representative of fatty acids is alpha-linolenic acid.

The purpose of this study was to determine the fatty acid composition of oils from fish, krill, flaxseed, walnut, pumpkin, olive, salad and sunflower, and potential effects on human health in their consumption.

Key words: fatty acid composition, fish and krill oils, vegetable oils
Abbreviations: ALA – alpha-linolenic acid, AHA – American Heart Association, DHA – Docosahexaenoic acid, DPA – Docosapentaenoic acid, EPA – Eicosapentaenoic acid, LA – linoleic acid, CLA – Conjugated linoleic acid, CRP – C-reactive protein, CVD – Cardiovascular diseases, MUFA – Monounsaturated fatty acids, PMS – Premenstrual syndrome, PUFA-Polyunsaturated fatty acids, SDA – Stearidonic acid, SFA – Saturated fatty acids

Introduction

With the increasing demands of the consumers towards healthier food, the dietary fats from animal and vegetable origin have been gaining more and more attention as an important source of bioactive compounds.

Dietary fats consist of a mixture of different fatty acids that are classified as saturated, mono-unsaturated (MUFA) and polyunsaturated (PUFA) fatty acids. Further, the unsaturated ones are classified into omega series, being ω-9, ω-3 and ω-6. While ω-9 are nonessential for humans, certain omega-3 and omega-6 polyunsaturated fatty acids (PUFA) are considered as essential fatty acids, as they are not produced by the human body, and are supplied through the food. Alpha-linolenic acid (ALA) omega-3 fatty acid, and linoleic acid (LA) omega-6 fatty acid are essential fatty acids to humans. ALA is a precursor of two important long chain omega-3 fatty acid eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Major sources of vegetable origin of ALA are walnuts, flaxseed, flaxseed oil, canola oil and soybean oil, while EPA and DHA are found primarily in fatty fish. LA was established in unmodified vegetable oils from corn, cotton, sesame and sunflower. Metabolism of ALA and LA is associated with interaction with certain enzymes and therefore is transformed in two ways. First, they are unsaturated because of the loss of hydrogen atoms, thereby increasing the number of double bonds therein. Secondly these fatty acids can be made longer by the addition of carbon atoms to the chain-elongation. This type of reaction allows the conversion of ALA to EPA and DHA. These long chain fatty acids ultimately form chemical compounds known as eicosanoids (James et al., 2000; Izquierdo et al., 2005; Innis, 2007; Simopoulos, 2008; Riediger et al., 2009). The combination of vegetable oil and marine sources of omega-3 fatty acid gives a positive effect on reducing the cardiovascular disease (CVD) (Gebauer et al., 2006; McKay and Sibley, 2009), lower blood sugar and reduce inflammation (Hunter, 1990; Drevon, 1992; Wilett et al., 1995; Harris, 1997; Schmidt,

**Corresponding author*: director@ikht.bg

1999; Connor W., 2000; Williams, 2000; Albert et al., 2002; Lovejoy et al., 2002; Finnegan et al., 2003; Kris-Etherton et al., 1999; Mensink et al., 2003; Williams and Burdge, 2006) Omega-3 have the potential to prevent cancer (Vlaykova et al., 2013) and are important for the proper functioning of the vital organs such as brain and eyes, in combination with vitamins and carotenoids, they protect human skin from sun damage (Boelsma et al., 2001).

The aim of this study is to determine the fatty acid composition of fish oil, krill oil, flaxseed oil, walnut oil, pumpkin oil, olive oil extra virgin, salad mix olive oil and sunflower oil, and potential effects on human health in their consumption.

Materials and Methods

The studies are conducted with different oils purchased commercially:

Fish oil dietary supplement "FITOFARM" Ltd.- Troyan batch: L 022 013;

Neptune Krill Oil, dietary supplement, „Neptune Technologies & Bioressources" Inc- Canada, batch: L 1302181;

Flaxseed oil, unrefined cold-pressed, Balcho Agro Product Ltd batch: L3218;

Walnut oil, unrefined cold-pressed, Balcho Agro Product Ltd batch: L 2824;

Pumpkin oil, unrefined cold-pressed, Balcho Agro Product Ltd batch: L3112;

Olive oil extra virgin, Greece, Minerva SA Edible Oils Enterprises, Ateenes, Greece, batch: EL 40005;

Salad Extra Virgin olive oil mix, Nutria SA, Greece, batch: L 0407;

Sunflower oil „Lazur", 100% refined, „Koel-H" EOOD, Bulgaria, batch: L -1875A.

The extraction of total lipids is carried out by the method of Bligh and Dyer (1959), using chloroform and methanol in a ratio of 1: 2. The methyl esters of the fatty acids were analyzed using a Shimadzu gas chromatograph-2010 (Kyoto, Japan). The analysis was performed on a capillary column CP7420 (100m x 0,25mm id, 0,2μm film, Varian Inc., Palo Alto, CA), with a carrier gas-hydrogen make-up gas nitrogen. Programmed mode is the temperature of the furnace for five steps: initial temperature of 51ºC which was maintained for 8 min, then increased at a 10ºC/min to 170ºC and maintained for 20 minutes, then increase of 4ºC/min to 186ºC and maintained for 19 minutes, again increase of 4ºC/min to 220ºC and with 2ºC/min to 240 ºC to complete the process.

Results and Discussion

The content of saturated fatty acids in the studied oils is presented in Table 1.

The main representatives of this group of fatty acids are myristic (C14:0), palmitic (C16:0) and stearic (C18: 0) acids. The fish and krill oil have considerably higher content of myristic and palmitic acids compared to the vegetable oils, however in the latter higher levels of stearic acid is observed. Flaxseed oil possess the lowest content of palmitic acid. According to Dogan and Akgul (2005), nut oils contain palmitic acid from 5.6% to 5.8% and trace amounts of myristic acid < 0.1%, which is in line with our results.

Table 2 presents the content of monounsaturated fatty acids (g/100 g fat) in the different oils. A total of 25 MUFA were identified in this study. Among them with highest content are C-18: 1c9. It is in highest contents in the pumpkin and olive oils, followed by the fish and sunflower oils, whereas the krill oil possesses the lowest.

Unconventional oil crops are important because they have specific chemical properties and can be used as food additives. Scientific experience indicates that the application of pumpkin seed oil on rats improved their lipid profile and

Table 1
Content of saturated fatty acids (g/100 g) in investigated oils

Saturated fatty acids	Fish oil	Krill oil	Flaxseed oil	Walnut oil	Pumpkin oil	Olive oil	Salad oil	Sunflower oil
C-14:0	5.18	8.76	0.07	0.06	0.12	0.02	0.08	0.17
C-15:0	0.34	0.33	0.02	0.02	0.01	0.01	0.01	0.02
C-16:0	14.29	20.43	5.72	6.11	12.32	13.18	7.38	7.54
C-17:0	0.24	1.42	0.06	0.06	0.08	0.15	0.04	0.06
C-18.0	3.02	1.19	5.81	2.43	5.24	27.19	17.04	16.43
C-20:0	0.32	0.08	0.19	0.08	0.37	0.21	0.14	0.16
C-22:0	0.32	0.21	0.15	0.02	0.13	0.00	0.07	0.07
C-23:0	0.00	0.00	0.01	0.01	0.04	0.00	0.00	0.01
C-24:0	0.04	0.00	0.03	0.00	0.07	0.00	0.00	0.00
C-25:0	0.00	0.04	0.00	0.00	0.00	0.00	0.01	0.01

Table 2
Monounsaturated fatty acids (g 100 g fat) in the tested oils

Monounsaturated fatty acids	Fish oil	Krill oil	Flaxseed oil	Walnut oil	Pumpkin oil	Olive oil	Salad oil	Sunflower oil
C-12:1ω1	0.00	0.03	0.01	0.02	0.02	0.02	0.01	0.04
C-14:1ω5	0.02	0.03	0.00	0.01	0.00	0.01	0.00	0.02
C-15:1ω5	0.06	0.06	0.00	0.00	0.00	0.00	0.00	0.00
C-16:19tr	0.29	0.42	0.01	0.00	0.00	0.02	0.00	0.00
C-16:1ω7	0.20	4.25	0.08	0.10	0.12	0.48	0.12	0.15
C-16:2ω4	0.59	0.67	0.00	0.01	0.01	0.00	0.00	0.00
C-17:1ω7	0.17	0.10	0.02	0.02	0.03	0.07	0.02	0.02
C-16:3ω4	0.50	0.55	0.00	0.00	0.00	0.00	0.00	0.01
C-18:1t4	0.03	0.02	0.00	0.01	0.02	0.11	0.10	0.12
C-18:1t5/6/7	0.00	0.00	0.00	0.00	0.01	4.13	1.44	1.45
C-18:1t9	0.03	0.00	0.02	0.01	0.02	8.89	4.21	4.88
C-18:1t10	0.07	0.02	0.02	0.02	0.01	3.06	3.54	3.01
C-16:4ω1	0.01	0.01	0.01	0.02	0.03	0.00	0.00	0.00
C-18:1t11	1.28	1.32	0.00	0.01	0.00	1.53	2.86	2.60
C-18:1c9/C-18:1t12/13/	29.91	9.49	19.04	17.45	37.20	36.52	22.36	27.03
C-18:1t15/C-18:1c11	3.27	5.97	0.58	0.72	0.67	1.22	1.16	1.15
C-18:1c12	0.02	0.05	0.00	0.00	0.00	0.39	1.30	1.06
C-18:1c13	0.15	0.25	0.01	0.01	0.01	0.14	0.22	0.23
C-18:1t16	0.00	0.01	0.00	0.00	0.00	0.13	0.22	0.25
C-18:1c14	0.00	0.01	0.01	0.00	0.00	0.14	1.10	1.02
C-18:1c15	0.02	0.04	0.03	0.00	0.00	0.01	0.04	0.12
C-20:1ω9	4.04	0.65	0.10	0.18	0.09	0.02	0.02	0.04
C-22:1ω11	3.33	0.53	0.01	0.01	0.01	0.00	0.00	0.00
C-22:1ω9	0.05	23.24	0.07	0.02	0.01	0.00	0.00	0.00
C-24:1ω9	0.20	0.10	0.00	0.00	0.00	0.00	0.00	0.01

liver function, and may be administered in the treatment of hypercholesterolemia (Ramadan et al., 2011), and the content of oleic acid may rich 38%, which is in agreement with our results. Pumpkin seeds are used in many countries for production of oil or protein. The fat content in different varieties of pumpkins varies from 38–60%. Due to the high content of unsaturated fatty acids, oil from the seeds of squash used in diets (Tsaknis et al., 1997, Vibhute et al., 2013). Pumpkin seed oil is traditionally used in medicine in many countries such as China, former Yugoslavia, Argentina, India, Mexico, Brazil and America and is used to treat disorders of the prostate gland and bladder, caused by hyperplasia. Pumpkin seed extract has antidiabetic, antitumor, antibacterial, anticancer, antioxidant and antimutagenic effect, has also been found that there reducing serum cholesterol. The health benefits of pumpkin seed oil due to their contents of macro- and micronutrients proteins, triterpenes, lignans, phytosterols, PUFA, antioxidant phenolic compounds, carotenoids, tocopherol and minerals (Ardabili et al., 2011). Used in the treatment of irritable bowel syndrome, inflammation of the prostate, atherosclerosis, kidney stones and regulate cholesterol levels in blood plasma. The high content of unsaturated fatty acids in the oil of pumpkin seeds, allows to replace the oils with a high content of saturated fatty acids in the food industries (Stevenson et al., 2007).

Olive oil is an example of a functional food with different components that may contribute to the overall therapeutic characteristics. Olive oil is known for its high levels of MUFA and also as a good source of phytochemicals including polyphenolic compounds, squalene and α-tocopherol (Stark and Madar, 2002; Hwang et al., 2010). Olive oil is the oil obtained from the fruit of the olive tree, traditionally grown in the region of the Mediterranean basin. The composition of the oil depends on the quality of the feedstock, the technological processing and storage conditions. Olive oil is one of the healthiest sources of fat in human nutrition, due to the high content of MUFA with a basic agent oleic acid (55-83%) (Salimon and Farhan, 2012; Esmaeili et al., 2012; Matthäus and Özcan, 2011; León et al., 2004; Dabbou et al., 2011; Mailer, 2006; Rondanini et al., 2011; Hashempour et

al., 2010). Olive oil is a major source of dietary fat in the Mediterranean region and the population have a lower incidence of chronic degenerative diseases, especially coronary heart disease, breast, skin and colon cancer. Products derived from olives in ancient times were used as aphrodisiacs, softeners, sedatives, tonics, laxatives and dietary supplement. Traditionally they are used to treat colic, alopecia, paralysis, rheumatic pain, sciatica and hypertension (Waterman and Lockwood, 2007). Extra virgin olive oil and its extracts protect against oxidative damage liver tissue by preventing excessive lipid peroxidation (Nakbi et al., 2010).

The highest content of vaccenic acid (C-18: 1t11) was presented in the salad mix and sunflower oil, the lowest in fish and krill oils, while in flaxseed, walnut and pumpkin oils this fatty acid was not detected. The maximum content of C-20:1n9 and C-22:1n11 acids was observed in fish oil, while the krill oil possessed the highest content of C-22:1n9.

The data on the content of polyunsaturated fatty acids (g/100g fat) in different oils is presented in Table 3. The linoleic acid (LA C-18:2c9,12/19:0) is the major component of PUFA in walnut, pumpkin, salad mix and sunflower oils.

In line with our results, Madawala et al. (2012), established a high content of PUFA in the oil from the nuts (71%), which determines its low oxidative stability. Linoleic acid content in the oil from the nuts varies between 49% to 55% (Özcan et al., 2010). In four varieties of walnuts, Dogan and Akgul (2005) determined linoleic acid in amounts of 49 to 54%. According to Tasan et al. (2011) in sunflower oil the linoleic acid (C18: 2) ranges from 61.37 to 62.65% in all sunflower oils, while the content of linolenic acid (C18: 3) is only 0.7% (Tasan et al., 2011).

The maximum content of alpha-linolenic acid (ALA C-18:3ω3) was determined in flaxseed oil, while very low content of ALA was found in olive, salad mix and sunflower oils.

Flaxseed is important functional food ingredient, rich in ALA, omega-3 fatty acid, lignans and fiber, which have potential benefits for human health by reducing the development of cardiovascular disease, atherosclerosis, diabetes, cancer, arthritis, osteoporosis, autoimmune and neurological disorders. Flaxseed oil as a functional food ingredient included in baked foods, juices, milk and dairy products, cakes, pasta and meat products (Goyal et al., 2014). Flaxseed oil is applied for the prevention and treatment of cancer as the primary focus is in breast cancer, colon cancer and prostate cancer (Young et al., 2005; Wiggins et al., 2013). Flaxseed oil is rich in ALA, like sunflower and safflower oil (Harris, 1997). Valencia et al. (2006) using flaxseed oil as a substitute for fat in the production of dry sausages established that anaerobic under vacuum for 5 months storage the quantitative content of ALA remains unchanged, unlike aerobic conditions, wherein it is established downward.

Stearidonic acid (SDA-18: 4 (ω-3)) in the krill oil is 2.2 times higher compared to its contents in the fish oil. Eicosadienoic acid (C20:2ω6) in fish oil is 0.72 g/100 g fat, while krill and walnut oils had a minimum content of this fatty acid (0.06 and 0.03 g/ 100 g, respectively). Dihomo-gamma-linolenic (C20: 3n6), arachidonic (C20: 4ω6), eicosatrienoic (C20:3ω3), dokosadienoic (C 22: 2ω6) acids are in higher concentration in the fish oil. The maximum content of eicosapentaenoic acid (EPA C-20:5ω3) was measured in fish oil as well. The other oils, except the krill oil, do not contain

Table 3
Polyunsaturated fatty acids (g/100 g fat) in the analyzed oils

Polyunsaturated fatty acids	Fish oil	Krill oil	Flaxseed oil	Walnut oil	Pumpkin oil	Olive oil	Salad oil	Sunflower oil
C-18:2t9,12	0.01	0.11	0.00	0.00	0.00	0.16	0.99	0.96
C-18:2c9,12/19:0	8.43	1.61	11.58	62.69	42.64	1.30	28.68	27.21
gC-18:3ω6	0.06	0.00	0.05	0.06	0.05	0.28	3.17	2.96
aC-18:3ω3	3.08	1.13	56.08	9.61	0.42	0.05	0.02	0.02
CLA9c,11t	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.21
C-18:4ω3	1.67	3.71	0.01	0.00	0.00	0.00	0.18	0.16
C-20:2ω6	0.72	0.06	0.01	0.03	0.00	0.00	0.00	0.00
C-20:3ω6	0.18	0.03	0.00	0.00	0.00	0.00	0.00	0.00
C-20:4ω6	0.52	0.39	0.00	0.00	0.00	0.00	0.00	0.00
C-20:3ω3	0.31	0.07	0.03	0.00	0.00	0.00	0.00	0.00
C-20:5ω3	8.69	0.04	0.00	0.00	0.00	0.00	0.00	0.00
C-22:2ω6	0.07	0.05	0.02	0.02	0.06	0.00	0.00	0.04
C-22:5ω3	1.36	0.32	0.00	0.00	0.00	0.00	0.00	0.00
C-22:6ω3	6.09	10.20	0.02	0.02	0.00	0.00	0.00	0.00

this fatty acid. The highest content of docosahexaenoic acid (DHA C-22:6ω3) was determined in krill and fish oils, but not detected in the other oils. The content of EPA in fish oil may vary from 20 to 250 mg/g fatty acid and depend on the kind of fish from which it is produced (Gruger, 1967; Harris, 2004).

There are three main omega-3 fatty acids which have a beneficial effect on human health: alpha-linolenic acid, (ALA, C18: 3), eicosapentaenoic acid (EPA, C20: 5) and docosahexaenoic acid (DHA, C22: 6). ALA is an important fatty acid that is converted to the long chain omega-3 fatty acids such as EPA and optionally DHA. EPA and DHA are found mainly in fish and have demonstrated cardioprotective properties (Harper et al., 2006; Abdel-Moein et al., 2011; Das, 2008; Innis, 2000).

Numerous clinical studies have proven the health benefits in terms of cardiovascular and mental health of inclusion in the diet of long-chain omega-3 polyunsaturated fatty acids, namely eicosapentaenoic acid (EPA) and docosahexanoic acid (DHA). Some types of fish oils are good sources of omega-3 fatty acid, but are not suitable for use in food products, since they change organoleptic characteristics of the product and therefore it is preferred that the addition of various vegetable oils derived from oilseed crops, such as oil from pumpkin seeds, flax seeds and walnuts, which contain alpha-linolenic acid (Damude and Kinney, 2007). The use of fish and fish oil as a source of omega-3 fatty acids reduce the risk of cardiovascular disease, strokes and sudden death in secondary prevention, while the application of the source of ALA is useful for primary prevention of the above mentioned diseases (Wang et al., 2006)

Table 4 shows the content of branched fatty acids (g/100 g fat) in the investigated oils. The highest contents of C-14iso, C-15iso and C-17iso acids were determined in krill oil. Relatively high content of C-15iso and C-17iso acids were detected in fish oil.

Table 5 presents the total contents of the saturated, mono- and polyunsaturated fatty acids (g/100 g fat) in the analyzed oils. Conjugated linoleic acid (CLA) is represented only in salad oil (0.24 g/100 g fat) and sunflower oil (0.21 g/100 g

Table 4
Branched fatty acids (g 100 g fat) in the analyzed oils

Branched fatty acids	Fish oil	Krill oil	Flaxseed oil	Walnut oil	Pumpkin oil	Olive oil	Salad oil	Sunflower oil
C-13iso	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
C-13aiso	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
C-14iso	0.02	0.18	0.05	0.08	0.08	0.04	0.09	0.13
C-15iso	0.20	0.28	0.00	0.00	0.00	0.00	0.00	0.00
C-15aiso	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.01
C:16iso	0.01	0.00	0.00	0.00	0.00	0.02	0.01	0.01
C-17iso	0.28	0.71	0.00	0.00	0.00	0.01	0.00	0.00
C-17aiso	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.00
C-18iso	0.04	0.15	0.00	0.00	0.00	0.00	0.00	0.01

Table 5
Groups of fatty acids (g/100 g fat) in the analyzed oils

Groups of fatty acids	Fish oil	Krill oil	Flaxseed oil	Walnut oil	Pumpkin oil	Olive oil	Salad oil	Sunflower oil
å CLA	0.00	0.00	0.00	0.00	0.00	0.01	0.25	0.23
S C-18:1Trans-FA	4.69	7.33	0.63	0.78	0.73	19.08	13.53	13.46
S C-18:1Cis-FA	30.10	9.84	19.09	17.46	37.21	37.20	25.02	29.45
SFA	23.75	32.46	12.06	8.79	18.38	40.76	24.77	24.47
MUFA	44.24	47.82	20.02	18.62	38.26	56.89	38.72	43.21
PUFA	31.19	17.72	67.80	72.44	43.18	1.79	33.30	31.60
å É-3	21.19	15.46	56.14	9.63	0.43	0.05	0.20	0.19
å **ω**-6	10.02	2.30	11.66	62.81	42.75	2.12	34.14	32.23
å ω-6/Σω -3	0.47	0.15	0.21	6.52	100.17	41.62	168.03	167.03
Branched FA	0.63	1.40	0.06	0.09	0.09	0.07	0.10	0.17
CLA	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.21

fat). The total amount of trans-isomers of oleic acid (Σ C18: 1trans FA) is highest in olive, salad mix and sunflower oils and minimum in flaxseed, pumpkin and walnut oils. The total amount of cis-isomers oleic acid (Σ C18: 1cis) is highest in pumpkin and olive oils. The total content of MUFA is between 56.89 g/100 g fat in olive oil to 18.62 g/100 g fat in walnut oil, which is due to the content of oleic and vaccenic acids. In the range from 47.72 to 43.21 g/100 g fat was the content of MUFA in krill, fish and sunflower oils. The walnut and flaxseed oils possessed the highest content of PUFA. Twice lower was the content of PUFA in salad, sunflower and fish oils. Very low PUFA content was found in the olive oil as well.

The analyzed oils have different content in omega-3 fatty acid. The highest concentration was found in flaxseed oil, which is 2.6 to 5.8 times higher than the content in fish, krill and walnut oils. The other oils had very low omega-3 fatty acid content. In omega-6 fatty acids highest values was found in walnut oil. The content between 42.75 and 32.23 g/100 g fat were determined in pumpkin, sunflower and salad oils. The lowest one was found in olive and krill oils.

The ratio between the two groups of fatty acids omega-6/ omega-3 vary widely depending on the prevailing content of omega-3 or omega-6 fatty acids. Good quantitative ratio is found in fish, krill, flaxseed and walnut oils. In other oils because of its low content of omega-3- fatty acids is high between 100.17 and 168.03. It is believed that products with omega-6/ omega-3 ratio < 5 have a low risk factor for human health. The low ratio of omega-6/omega-3 fatty acid is more desirable to reduce the risk of many chronic diseases.

In Western diet the ratio of omega-6/omega-3 is 15 / 1-16.7 /1. Excessive amounts of omega 6 polyunsaturated fatty acids (PUFA) and a very high ratio of omega-6/omega-3 promote the pathogenesis of many diseases, including cardiovascular, cancer, inflammatory and autoimmune diseases. For their suppression is necessary to increase the content of omega -3 PUFA. In secondary prevention of cardiovascular diseases the ratio of omega-6/omega-3 4/1 reduced mortality by 70%. The ratio of 2.5/1 decreases cell proliferation of patients with colorectal cancer, whereas a ratio of 4/1 with the same amount of omega-3 PUFA has no effect. The low value of the omega-6/omega-3 in women w ith breast cancer is associated with decreased risk. Ratio 2-3/1 inhibits inflammation in rheumatoid arthritis patients, 5/1 has beneficial effects on asthma patients as a ratio of 10/1 has undesirable consequences. These studies indicate that the optimum ratio may vary depending on the disease. It is entirely possible therapeutic dose of omega 3 fatty acids depend on the severity of the disease (Simopoulos, 2002).

Data for the branched fatty acids (Table 4 and 5) show that the highest content is found in krill and fish oils, while vegetable oils varies from 0.06 (flaxseed oil) to 0.17 g/100 g fat (sunflower oil). They are positional isomers which have no relation to human nutrition.

Conclusions

Fatty acid analysis of fish, krill, flaxseed, walnut, pumpkin, olive, salad mix and sunflower oils gives us reason to summarized that:

Saturated fatty acids in vegetable oils are in relatively low concentration versus, olive and krill oils;

The oils are rich in unsaturated fatty acids from 58.7 to 91.06 g/100 g of fat, which would have a positive effect on dietary benefits, due to the high content of bioactive compounds – oleic, linoleic and linolenic acid in vegetable oils and eicosapentaenoic, docosahexaenoic and docosapentanoic fatty acids in fish and krill oils.

Conjugated linoleic acid is represented only in salad oil 0.24 g/100 g fat and sunflower oil 0.21 g/100 g fat.

From the point of view of omega-3-fatty acid the highest content was determined in flaxseed, fish, krill and walnut oils. These oils have good ratio of omega-6/omega-3 fatty acids. This gives us reason to believe that these oils are best suited for diet and healthy eating.

References

Abdel-Moein, N., E. Abdel-Moniem, D. Mohamed and E. Hanfy, 2011. Evaluation of the anti-inflammatory and anti-arthritic effects of some plant extracts. *Grasas y Aceites*, **62** (4): 365–374.

Albert, C., H. Campos, M. Stampfer, P. Ridker, J. Manson, W. Willett and J. Ma, 2002. Blood levels of long-chain n–3 fatty acids and the risk of sudden death. *N. Engl. J. Med.*, **346** (15): 1113–1118.

Ardabili, G., A., R. Farhoosh and M. Haddad Khodaparast, 2011. Chemical Composition and Physicochemical Properties of Pumpkin Seeds (Cucurbita pepo Subsp. pepo Var. Styriaka) Grown in Iran. *J. Agr. Sci. Tech.* 13: 1053–1063.

Bligh, E. and W. Dyer, 1959. A rapid method for total lipid extraction and purification. *Canadian Journal of Biochemistry and Physiology*, **37**: 911–917.

Boelsma, E., H. Hendriks and L. Roza, 2001. Nutritional skin care: health effects of micronutrients and fatty Acids. *Am. J. Clin. Nutr.,* **73**: 853–864.

Connor, W., 2000. Importance of n-3 fatty acids in health and disease. *Am. J. Clin. Nutr.*, **71**: 171S–175S.

Dabbou, S., F. Brahmi, S. Dabbou, M. Issaoui, S. Sifi and M. Hammami, 2011. Antioxidant capacity of Tunisian virgin olive oils from different olive cultivars. *African Journal of Food Science and Technology*, **2** (4): 092–097.

Damude, H. and A. Kinney, 2007. Engineering oilseed plants for a sustainable, land-based source of long chain polyunsaturated fatty acids. *Lipids*, **42** (3): 179–185.

Das, U., 2008. Essential fatty acids and their metabolites could function as endogenous HMG-CoA reductase and ACE enzyme inhibitors, anti-arrhythmic, anti-hypertensive, anti-atherosclerotic, anti-inflammatory, cytoprotective, and cardioprotective molecules. *Lipids in Health and Disease,* **7**: 37–55.

Dogan, M. and A. Akgul, 2005. Fatty acid composition of some walnut (*Juglans regia* L.) cultivars from east Anatolia. *Grasas y Aceites*, **56** (4): 328–331.

Drevon, C., 1992. Marine oils and their effects. *Nutrition Reviews*, **50** (4): 38–45.

Esmaeili, A., F. Shaykhmoradi and R. Naseri, 2012. Comparison of oil content and fatty acid composition of native olive genotypes in different region of Liam, Iran. *International Journal of Agriculture and Crop Sciences*, **4** (8): 434–438.

Finnegan, Y., A. Minihane, E. Leigh-Firbank, S. Kew, G. Meijer, R. Muggli, P. Calder and C. Williams, 2003. Plant- and marine-derived n_3 polyunsaturated fatty acids have differential effects on fasting and postprandial blood lipid concentrations and on the susceptibility of LDL to oxidative modification in moderately hyperlipidemic subjects [1–3]. *Am. J. Clin. Nutr.*; **77**: 783–795.

Gebauer, S., T. Psota, W. Harris and P. Kris-Etherton, 2006. n_3 Fatty acid dietary recommendations and food sources to achieve essentiality and cardiovascular benefits1–3. *Am. J. Clin. Nutr.*, **83**: 1526–1535.

Goyal, A., V. Sharma, N. Upadhyay, S. Gill and M. Sihag, 2014. Flax and flaxseed oil: an ancient medicine & modern functional food. *Journal of Food Science and Technology,* **51** (9): 1633–1653.

Gruger, E., 1967. Fatty Acid Composition of Fish Oils. *United States Department of the Interior Fish and Wildlife Service*, 2–30.

Harper, C., M. Edwards, A. De Filipis and T. Jacobson, 2006. Flaxseed oil increases the plasma concentrations of cardioprotective (n-3) fatty acids in humans. *J. Nutr.*, **136**: 83–87.

Harris, W., 1997. N-3 Fatty acids and serum lipoproteins: human studies, *Am. J. Clin. Nutr.,* 65: 1645- 1654.

Harris, W., 2004. Fish oil supplementation: Evidence for health benefits. *Cleveland Clinic Journal of Medicine,* **71** (3): 208–221.

Hashempour, A., R. F. Ghazvin, D. Bakhshi and A. Sanam, 2010. Fatty acids composition and pigments changing of virgin olive oil *(Olea europea* L.) in five cultivars grown in Iran. *Australian Journal of Crop Science*, **4** (4): 258–263.

Hunter, J., 1990. n-3 Fatty acids from vegetable oils. *Am. J. Clin. Nutr.*, **51**: 809-814.

Hwang, J., H. Jun and E. Shim, 2010. Rates of change in tissue fatty acid composition when dietary sobean oil is switched to olive oil. *Journal of Health Science*, **56** (3): 275–286.

Innis, S., 2000. The role of dietary n–6 and n–3 fatty acids in the developing brain. *Dev. Neurosci.*, **22**: 474–480.

Innis, S., 2007. Fatty acids and early human development. *Early Human Development,* **83**: 761–766.

Izquierdo, M., D. Monteroa, L. Robainaa, M. Caballeroa, G. Rosenlundb and R. Gine´sa, 2005. Alterations in fillet fatty acid profile and flesh quality in gilthead seabream (*Sparus aurata*) fed vegetable oils for a long term period. Recovery of fatty acid profiles by fish oil feeding. *Aquaculture*, **250**: 431–444.

James, M., R. Gibson and L. Cleland, 2000. Dietary polyunsaturated fatty acids and inflammatory mediator production, *Am. J. Clin. Nutr.,* **71**: 343–348.

Kris-Etherton, P., S. Yu-Poth, J. Sabaté, H. Ratcliffe, G. Zhao and T. Etherton, 1999. Nuts and their bioactive constituents: effects on serum lipids and other factors that affect disease risk. *Am. J. Clin. Nutr.*, **70**: 504–511.

Kris-Etherton, P., D. Taylor, S. Yu-Poth, P. Huth, K. Moriarty, V. Fishell, R. Hargrove, G. Zhao and T. Etherton, 2000. Polyunsaturated fatty acids in the food chain in the United States. *Am. J. Clin. Nutr.*, **71**: 179–188.

León, L., M. Uceda, A. Jiménez, L. Martín and L. Rallo, 2004. Variability of fatty acid composition in olive (*Olea europaea* L.) progenies. *Spanish Journal of Agricultural Research*, **2** (3): 353–359

Lovejoy, J., S. Smith, C. Champagne, M. Most, M. Lefevre, J. Delany, Y. Denkins, J. Rood, J. Veldhuis and G. Bray, 2002. Effects of diets enriched in saturated (palmitic), monounsaturated (oleic), or trans (elaidic) fatty acids on insulin sensitivity and substrate oxidation in healthy adults. *Diabetes Care,* **25**: 1283–1288.

Madawala, S., S. Kochhar and P. Dutta, 2012. Lipid components and oxidative status of selected specialty oils. *Grasas y Aceites*, **63** (2): 143–151.

Mailer, R., 2006. Chemistry and quality of olive oil. *Primefact,* 227 (REPLACES AGNOTE DPI-368).
http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/87168/pf227-Chemistry-and-quality-of-olive-oil.pdf

Matthäus, B. and M. Özcan, 2011. Determination of fatty acid, tocopherol, sterol contents and 1,2- and 1,3-diacylglycerols in four different virgin olive oil. *Journal of Food Processing and Technology*, **2** (4): 117–120.

McKay, D. and D. Sibley, 2009. Omega-3 Fatty Acids from Walnuts.
www.NutritionDimension.com

Mensink, R., P. Zock, A. Kester and M. Katan, 2003. Effects of dietary fatty acids and carbohydrates on the ratio of serum total to HDL cholesterol and on serum lipids and apolipoproteins: a meta-analysis of 60 controlled trials , *Am. J. Clin. Nutr.*, **77**: 1146–1155.

Nakbi, A., W. Tayeb, A. Grissa, M. Issaoui, S. Dabbou, I. Chargui, M. Ellouz, A. Miled and M. Hammami, 2010. Effects of olive oil and its fractions on oxidative stress and the liver's fatty acid composition in 2,4-Dichlorophenoxyacetic acid-treated rats. *Nutrition & Metabolism*, **7** (1): 80–91.

Özcan, M., C. İman and D. Arslan, 2010. Physico-chemical properties, fatty acid and mineral content of some walnuts (*Juglans regia* L.) types. *Agricultural Sciences,* **1**: 62–67.

Ramadan, M., R. Zayed, M. Abozid and M. Asker, 2011. Apricot and pumpkin oils reduce plasma cholesterol and triacylglycerol concentrations in rats fed a high-fat diet. *Grasas y Aceites*, **62** (4): 443–452.

Riediger, N., R. Othman, M. Suh and M. Moghadasian, 2009.

A systemic review of the roles of n-3 fatty acids in health and disease. *Journal of the American Dietetic Association*, **109**: 668–679.

Rondanini, D., D. Castro, P. Searles and M. Rousseaux, 2011. Fatty acid profiles of varietal virgin olive oils (*Olea europaea* L.) from mature orchards in warm arid valleys of Northwestern Argentina (La Rioja). *Grasas y Aceites*, **62** (4): 399–409.

Salimon, J. and N. Farhan, 2012. Physiochemical properties of Saudi Extra Virgin Olive Oil. *International Journal of Chemical and Environmental Engineering*, **3** (3): 205–208.

Schmidt, E., H. Skou, J. Christensen and J. Dyerberg, 1999. n-3 fatty acids from fish and coronary artery disease: implications for public health. *Public Health Nutrition*, 3 (1): 91–98.

Simopoulos, A., 1999. Essential fatty acids in health and chronic disease, *Am. J. Clin. Nutr.,* **70**: 560–569.

Simopoulos, A., 2002. The importance of the ratio of omega-6/omega-3 essential fatty acids. *Biomedicine & Pharmacotherapy*, **56** (8): 365–379.

Simopoulos, A., 2008. The importance of the omega-6/omega-3 fatty acid ratio in cardiovascular disease and other chronic diseases. *Exp. Biol. Med.*, **233** (6): 674–688.

Stark, A. and P. Madar, 2002. Olive Oil as a Functional Food. *Epidemiology and Nutritional Approaches. Nutrition Reviews*, **60**: 170–176.

Stevenson, D., F. Eller, L. Wang, J. Jane, V. K. Wang and G. Inglett, 2007. Oil and tocopherol content and composition of pumpkin seed oil in 12 cultivars. *J. Agric. Food Chem.*, **55** (10): 4005–4013.

Tasan, M., U. Gecgel and M. Demirci, 2011. Effects of storage and industrial oilseed extraction methods on the quality and stability characteristics of crude sunflower oil (*Helianthus annuus* L.). *Grasas y Aceites*, **62** (4): 389–398.

Tsaknis, J., S. Lalas and E. Lazos, 1997. Characterization of crude and purified pumplcin seed oil. *Grasas y Aceites,* **48** (5): 267-–272.

Valencia, I., D. Ansorena and I. Astiasara´n, 2006. Stability of linseed oil and antioxidants containing dry fermented sausages: A study of the lipid fraction during different storage conditions. *Meat Science,* **73**: 269–277.

Vibhute, B., D. Bhide, V. Karadbhajne, A. Kulkarni and R. Khotpal, 2013. Fatty acid profile of pumpkin and bael seed lipids of Central India region. *RRJBS*, **2** (2): 1-2.

Vlaykova, T., I. Dimitrova, I. Pavlov and T. Tacheva, 2013. Cancer prevention – dietary anticarcinogens. *Science & Technologies*, **3** (1): 381–392.

Wang, C., W. Harris, M. Chung, A. Lichtenstein, E. Balk, B. Kupelnick, H Jordan and J. Lau, 2006. n-3 Fatty acids from fish or fish-oil supplements, but not α-linolenic acid, benefit cardiovascular disease outcomes in primary- and secondary-prevention studies: a systematic review. *Am. J. Clin. Nutr.*, **84**: 5–17.

Waterman, E. and B. Lockwood, 2007. Active components and clinical applications of olive oil. *Alternative Medicine Review*, **12**.(4): 331–342.

Wiggins, A., J. Mason and L. Thompson, 2013. Beneficial influence of diets enriched with flaxseed and flaxseed oil on cancer. cancer chemoprevention and treatment by diet therapy. *Evidence-based. Anticancer Complementary and Alternative Medicine,* **5**: 55–89.

Wilett, W., F. Sacks, A. Trichopoulou, G. Drescher, A. Ferro-Luzzi, E. Helsing and D. Trichopoulos, 1995. Mediterranean diet pyramid: a cultural model for healthy eating. *Am. J. Clin. Nutr.*, **61**: 1402–1406.

Williams, C., 2000. Dietary fatty acids and human health. *Ann. Zootech*., **49**: 165–180.

Williams, C. and G. Burdge, 2006. Long-chain n-3 PUFA: plant v. marine sources. *Proceedings of the Nutrition Society*, **65**: 42–50.

Young, G., J. Conque and R. Thomas, 2005. Effect of randomized supplementation with high dose olive, flax or fish oil on serum phospholipid fatty acid levels in adults with attention deficit hyperactivity disorder. *Reprod. Nutr. Dev*., **45**: 549–558.

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