Evaluation of Fatty Acids Composition and Quantity in Raw and Processed Salmon, Herring and Mackerel Products in Lithuanian Market

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Abstract. *Fatty acids (FA) and their composition are very important for human nutrition. Fish products are one of the most beneficial sources of FA for human health; therefore, it is very important to know which products in the Lithuanian market are the most suitable for consumers.*

The aim of the study was to determine the content of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), the quantity and ratio of omega 6 and omega 3 fatty acids(n-6/n-3) in the raw material of salmon, herring and mackerel and their salted and smoked products, and to calculate the atherogenic (AI) and thrombogenic (TI) indices of these products.

The study was carried out in 2019–2020. A test sample for FA analysis was prepared according to LST EN ISO 12966-2:2011 standard. The content of FA was determined by gas chromatography using a flame ionization detector. Chromatographic analysis of fatty acid methyl esters was performed with Shimadzu GC - 2010 (Japan) gas chromatograph, using a BPX - 70, 120 m column according to the LST EN ISO 15304:2003/AC:2005 standard.

Compared with heat-treated products, fish raw material (fillets) had a higher content of PUFA ($P < 0.05$), higher levels of omega 3 FA (n-3) ($P < 0.05$), and their n-6/n-3 ratio was reliably lower. Salmon products had the healthiest FA composition for humans, the highest amount of omega 3 FA and the most suitable for human diet n-6/n-3 ratio.

The most favourable indices of atherogenicity and thrombogenicity (AI – 0.13, TI – 0.1) for human diet in tested fish product samples were calculated in the raw material of Atlantic salmon fillet and were slightly higher than in cold smoked mackerel (AI – 0.23, TI – 0.25). Moreover, the assessment of correlation relationships between individual indicators showed that the ratio n-6/n-3 decreased with increasing quantity of PUFA (coefficient r =–0.602 in salmon; r = –0.628 in mackerel; r = –0.831 in herring products).

Introduction

Fish and seafood product consumption is very important in human nutrition. According to Food and Agriculture Organization (FAO) data, global world fish production in 2018 year was 179 million tonnes, of which approximately 156 million tonnes were used for human consumption (FAO, 2020), and 3 billion people around the world consume fish and other marine organisms as a source of proteins (Tveteras et al., 2012) and fats.

Usually, fish fats are used in the human diet as a concentrated form of energy which helps to protect body from cold (Payne et al., 2018), regulate body cholesterol metabolism (Chiu et al., 2018; Hirako et al., 2010) and protect body tissues and organs. They also play an essential role in carrying fat-soluble vitamins, and take part as saturated (SFA), monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA) in the human diet. According to scientific literature, PUFA, especially omega-3 fatty acids – eicosapentaenoic (EPA) and docosahexaenoic acids (DHA) – are very significant for human health in both disease prevention and health status improvement (Oscarsson & Hurt-Camejo, 2017; Murillo et al., 2014).

The role of omega n-3 fatty acids in prevention and management of cardiovascular disease is evident; it reduces low-density lipoprotein, inhibits cholesterol production (Pedro-Botet et al., 2019), has a positive effect on brain function and neurodevelopment, reduces inflammation and plays a role on psychological and cognitive function (Scotio & Mjos, 2012).

The biological effect of omega-6 fatty acids is largely mediated during physical activity and inflammation by their conversion to n-6 eicosanoids that bind to diverse receptors found in every tissue of the body. Since n-3 and n-6 fatty acids compete for the same enzymes for desaturation and elongation, and each class of PUFA has a different effect on human health, an appropriate ratio of both FA is crucial. Some studies indicate that human beings evolved on the diet with n-6 to n-3 fatty acids ratio of approximately 1:1 (Simopouls, 2008). Other authors

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state that a ration between 1:1 and 5:1 is beneficial to human health (Strobel et al., 2012, Gebauer et al., 2006), while nowadays this ratio can reach up to 20:1 in Western diets.

Fatty acids can have an impact in preventing heart diseases, lower the atherosclerotic processes, high blood pressure, inflammation, mental health disorders (Mozafarian et al., 2006), diabetes, digestive disorder, autoimmune disease, cancer (de Roos al., 2013), and have a positive effect in foetus development and adult health (Chowdhury et al., 2020; Gale et al., 2008).

The research interest related to trans fatty acids isomers (TFAI) in food and their significance to human health increases every year. According to researchers, TFAI have been implicated in the aetiology of various metabolic and functional disorders (Trattner et al., 2015). The main concern about its health effects arose due to the structural similarity of these isomers to saturated fatty acids, the lack of specific metabolic functions, and their competition with essential fatty acids. The metabolic effect of trans isomers is the main question for biochemists, nutrition specialists and epidemiologists. It is known that fish processing methods have different effects on nutritional, physical and chemical compositions, including fat and fatty acids (Abraha et al., 2018).

Fish fatty acid profiles, quantity and relationships are very important to human health. The other significant lipid quality indicators of food products are atherogenic (AI) and thrombogenic (TI) indices, which depend on the relative contents of particular fatty acid groups and may indicate total lipid quality in food and their potential effect on the development of coronary disease (Ulbricht et al., 1991). These rates can be used to compare the influence of fat fraction wellness in various foods.

So, the aim of the study was to determine the content of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), the quantity and ratio of omega 6 and omega 3 fatty acids(n-6/n-3) in the raw material of salmon, herring and mackerel and their salted and smoked products, presented in the Lithuanian market, and to calculate the atherogenic (AI) and thrombogenic (TI) indices of these products.

Materials and methods

During this study, fatty acids SFA, MUFA, PUFA, TFAI, n-3, n-6, their ratio (n-6/n-3), AI and TI indexes were determined in raw and processed products of salmon (*Salmo salar*), herring (*Clupea harengus)* and mackerel (*Scomber scombrus),* presented in the Lithuanian retail market.

All types of fish products (3 samples from each raw fillets, salted, hot and cold smoked fish), were randomly purchased in supermarkets, shops and market places of Kaunas city, Lithuania. In total, 36 products, belonging to 4 assortment (raw fillets, salted, cold and hot smoked) groups, were taken for investigation.

Sample preparation. The composition of fatty acids was detected in intramuscular fish fat. The investigations were carried out in the Food Institute of Kaunas Technology University. All samples were homogenized with a homogeniser (Heidolph, Germany), and stored at +6–8°C in the refrigerator until further investigation. The samples were prepared according to the LST EN ISO 12966-2:2011 standard, where fatty acids were methylated using anhydrous 2 mol/l KOH methanol solution. The number of fatty acids was determined by the gas chromatography method using a flame ionization detector. Chromatographic analysis of fatty acids methyl esters was performed using gas chromatograph Shimadzu GC 17 A (Japan), using BPX – 70, 120 m column following methodology described in LST EN ISO 15304:2003/AC: 2005 standard. The analysis was done under the following conditions: column primary temperature was kept at +60°C, after 2 min., using 20°C/min speed was increased to +230°C and maintained for 45 min; injector temperature was +250°C; flame ionization detector temperature was +270°C; carrier gas was nitrogen.

Supelco 37 Component FAME Mix (Merck, USA) was used for fatty acids identification. The fatty acids tetradecen (C14:2) and hexadecen (C16:2) were identified by the means of interpolation. Each group of fatty acids in fish samples was calculated as a percentage (%) of the total amount (sum) of all FA (100%). The ratio of n-6/n-3 was calculated by dividing their total values. The atherogenic (AI) and thrombogenic (TI) indices were calculated according to Ulbricht and Southgate (1991) using the following formulas:

AI = [C12:0 + (C14:0 × 4) + C16:0] / (total unsaturated fatty acids), where:

C12 – the percentage of lauric acid in relation to TFA; C14 = the percentage of myristic acid in relation to TFA; and C16 = the percentage of palmitic acid in relation to TFA.

TI = $\sum$ (C14:0 + C16:0 + C18:0)/[0.5 × cis C18:1 + 0.5 × $\sum$ MUFA + 0.5 × $\sum$ (n-6) + 0.5× $\sum$ (n-3) + (n-3/n-6], where:

n-6 is fatty acids containing omega-6

n-3 is fatty acids containing omega-3.

Statistical analysis

All gathered data were analysed using statistical package SPSS for Windows 2.0 version (IBM Corp NY, USA). Significance of differences between treated samples was evaluated using Duncan's multiple range tests at a 5% confidence level. The Shapiro-Wilk test revealed the normal distribution of variables as well as TBC and TCC, which are expressed as mean ± standard error (SE). Correlation was analysed by Microsoft Excel statistical software (Microsoft Office Excel 2016, Microsoft Corp., Redmond, WA, USA).

Results

During this study, the composition and quantity

of fatty acids SFA, MUFA, PUFA, TFAI, n-3, n- 6, their ratio (n-6/n3), atherogenic and thrombogenic indexes in salmon, herring and mackerel raw, salted and smoked products were investigated.

Fatty acids composition and quantity in Atlantic salmon, herring and mackerel raw fillets

According to this study results, the highest quantity of SFA was determined in raw herring fillets and this amount was 1.5 times higher than in salmon and 1.2 times than in mackerel fillets, respectively (Fig. 1). Moreover, the obtained results among all investigated groups were statistically significant ($P < 0.05$).

MUFA quantity in Atlantic salmon raw fillets was 2.21 times ($P < 0.05$) higher than in herring and 2.24 times ($P < 0.05$) than in mackerel fillets.

The study results indicated that PUFA dominated in herring products, and this amount was 1.56 times higher than in Atlantic salmon and 1.24 times higher than detected in mackerel fillets. The results between all tested groups were statistically significant ($P < 0.05$).

According to our study results, the best n-6/n-3 ratio (1.38:1) was found in raw salmon, although the n-3 acids quantity in herring and mackerel fillets was higher compared with n-6 fatty acids. Due to this reason, the ratio between omega 6 to omega 3 fatty acids in these products was 0.17:1 and 0.57:1, respectively.

There were no statistically significant differences determined in TFAI between the samples obtained from raw salmon and mackerel groups, while in herring fillets, this quantity was 1.03 times ($P > 0.05$) higher than in mackerel products.

The calculated atherogenic and thrombogenic indices in raw fish fillet samples are presented in Table 1.

The data presented in Table 1 showed significant differences of atherogenic and thrombogenic indices related to fish species. According to our study results, their atherogenic indices ranged from 0.13 to 0.79, whereas thrombogenic indices values variated from 0.17 to 0.74, respectively. Therefore, Atlantic salmon raw fillet samples were most suitable for human diet.

Fatty acid composition and quantity in salted fish products

In order to compare fatty acids composition and quantity of salted herring, mackerel and salmon fillet products were evaluated. The highest amount of SFA was detected in the samples obtained from salted mackerel, and this amount was 1.33 times ($P < 0.05$) higher than in salmon, and 1.09 times ($P > 0.05$) than in herring, respectively (Fig. 2).

The statistically significant MUFA differences ($P < 0.05$) were found among all tested salted fish product groups. Moreover, the MUFA amount detected in salmon samples was 2.1 times higher than

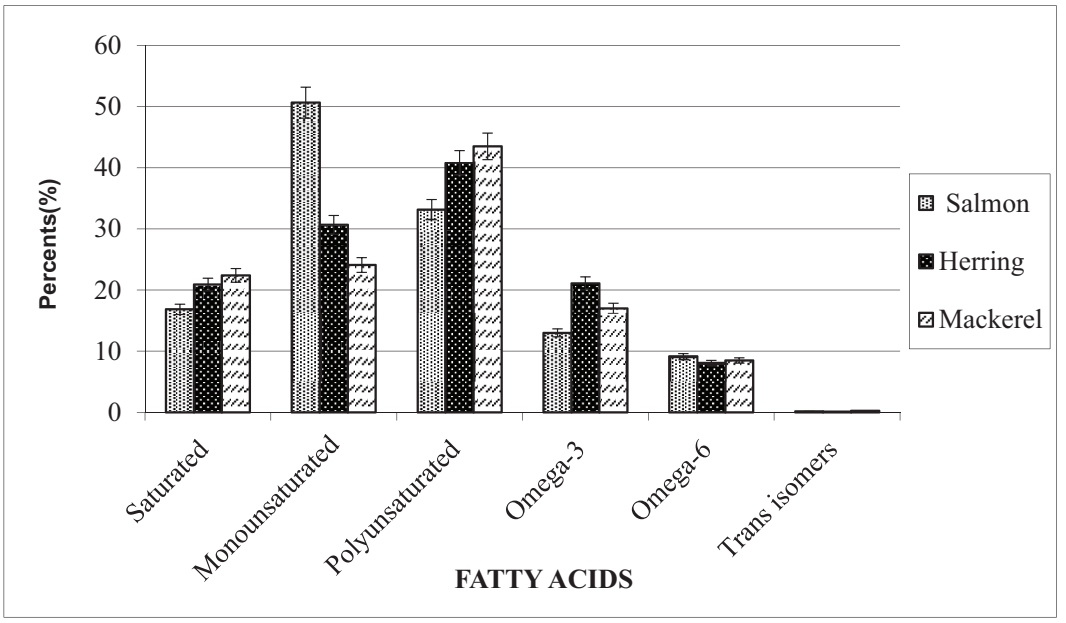

Fig. 1. Fatty acid composition in raw materials (salmon, herring, and mackerel fillets).

Table 1. Atherogenic (AI) and thrombogenic (TI) indices in Atlantic salmon, herring and mackerel raw fillets

Indices	Raw fillet		
	Salmon	Herring	Mackerel
Atherogenic	0.13*±0.02	0.77* ± 0.08	0.79* ± 0.07
Thrombogenic	0.17*±0.03	0.24 ± 0.06	0.74* ± 0.1

*Statistically significant values between groups ($P < 0.05$)

in mackerels and 1.65 times higher than in herrings' products, respectively.

The data presented in Fig. 2 showed that the highest amount of PUFA was detected in salted mackerel fillets. In comparison with herring and salmon product samples, the quantity of PUFA in salted mackerel products was 1.08 ($P > 0.05$) and 1.31 ($P < 0.05$) times higher than in previously mentioned products.

The higher amount of n-3 fatty was dominated in the samples of all tested salted fish products in comparison with the quantity of n-6 fatty acids. Moreover, the highest n-3 amount was detected in mackerels and the lowest in salted salmon products. Whereas, the higher percent of n-6 acids were dominated in salted salmon products, where their amount was 1.12 ($P > 0.05$) and 1.07 ($P > 0.05$) times higher than in herring and mackerel products, respectively.

The n-6/n-3 ratio depended on fish species in salted fish products, as it was 0.50:1 in mackerel, 0.38:1 in herring, and 0.70:1 in salmon samples.

It is important to note that the amount of TFAI in all tested salted fish products samples ranged from 0.10% to 0.24%. The study results indicated that the highest amount of TFAI was detected in mackerel and it was 2.4 times higher than in herring and 1.6 times higher than in salmon salted products. Moreover, the differences between tested fish species samples were statistically significant ($P < 0.05$).

The study results showed that the best AI and TI composition for human health was detected in salted salmon products (Table 2).

Statistically significant data were detected between the values of atherogenic and thrombogenic indices in Atlantic salmon and mackerel salted products.

Fatty acid composition and quantity in smoked fish products

In order to compare the impact of the smoking method on FA composition, the samples obtained from cold and hot smoked Atlantic salmon, herring and mackerel were investigated. It is important to note that there are some FA differences, related with fish species and the smoking method.

No significant SFA quantity differences ($P > 0.05$) were detected comparing cold and smoked fish product samples obtained from the same fish species. The SFA values of products, processed from various fish species ranged from 1.02 (in salmon) to 1.12 times (in mackerel). Therefore, the smoking method had no influence on the amount of SFA between the same fish species (Fig. 3).

Despite previous results, the statistically significant differences among the tested samples groups were detected in products processed from dissimilar fish species. According to this study results, the highest

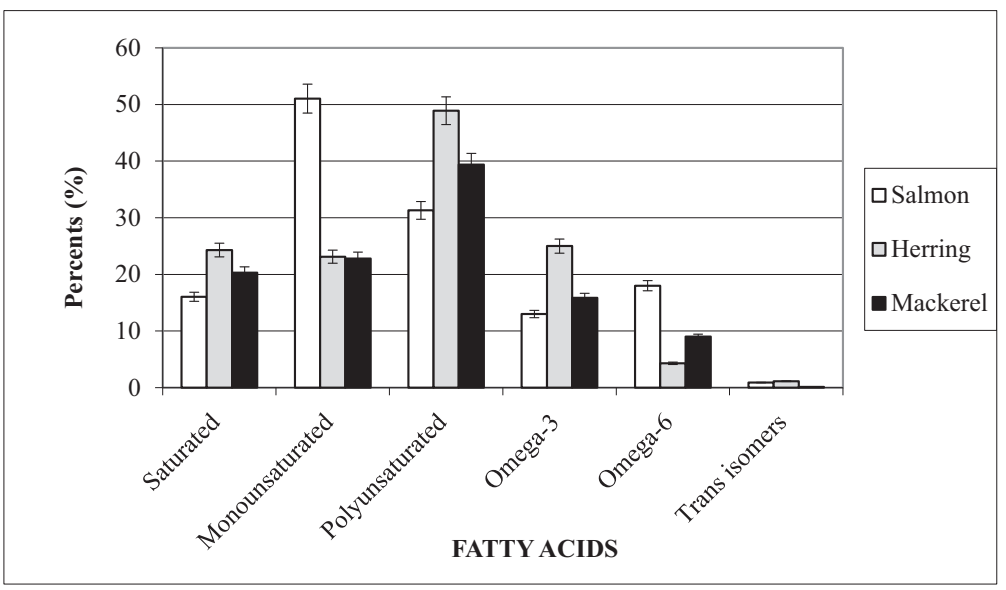

Fig 2. Fatty acid composition in salted fish products.

Table 2. Atherogenic (AI) and thrombogenic (TI) indices in Atlantic salmon, herring and mackerel salted products

Indices	Salted fish products		
	Salmon	Herring	Mackerel
Atherogenic	0.27* ± 0.03	0.64* ± 0.06	0.70* ± 0.07
Thrombogenic	0.21* ± 0.03	0.24 ± 0.04	0.69* ± 0.02

*Statistically significant values between groups ($P < 0.05$).

SFA amount was determined in mackerel and the lowest in salmon products. The biggest differences were determined between mackerel and smoked salmon products groups, where the results among groups ranged from 1.46 in cold smoked products to 1.53 times in hot smoked products, and were statistically significant ($P < 0.05$).

Contrary to previous results related to SFA quantity, the highest MUFA amount was detected in smoked salmon, and the lowest in mackerel products. There were no significant differences comparing the amount of MUFA between cold smoked and hot smoked products of the same fish species. The differences between them ranged from 1.11 (herring) to 1.35 times in salmon products ($P > 0.05$). However, the highest percent of MUFA was determined in salmon hot smoked products and the lowest in herring cold and hot smoked production.

The data presented in Fig. 3 showed that the highest amount of PUFA was detected in cold and hot smoked mackerel, and the lowest in salmon smoked products. Their differences among groups ranged from 1.44 to 1.48 times ($P < 0.05$).

In conclusion, it was determined that cold smoked fish products had higher PUFA amount than hot smoked products. The study results showed that the quantity of n-3 in all tested cold smoked fish products was 2.39 times ($P < 0.05$) higher than in the hot smoked samples, where differences ranged from 2.12 times in mackerel to 2.84 times in salmon. The results between tested groups were statistically significant ($P < 0.05$).

It is important to note that the quantity of n-3 depends on the smoking method in products, processed from different kinds of fish. A higher amount of n-3 was found in cold smoked fish than in hot smoked products. The quantity of TFAI determined in smoked fish product samples ranged from 0.97% (hot smoked mackerel) to 3.10% (cold smoked salmon) products. There were no statistically significant data found comparing the amount of TFAI between different fish smoking methods, except from salmon products as the difference between cold and hot smoked fish groups was 2.21 times ($P < 0.05$).

The omega 6 to omega 3 ratio between smoked fish products is presented in Table 4.

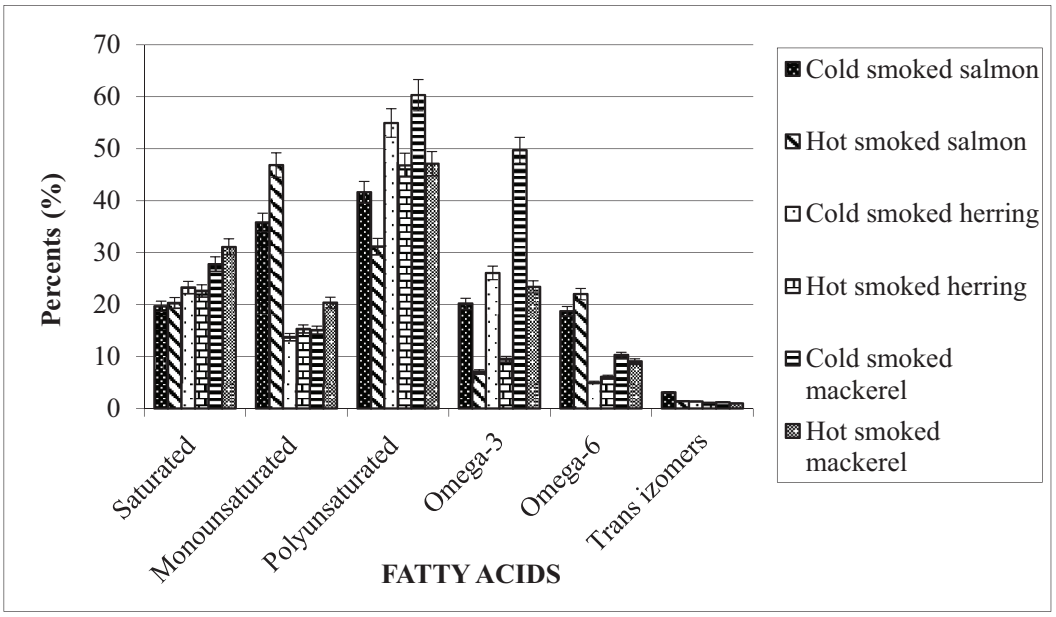

Fig. 3. Fatty acid composition in cold and hot smoked fish products.

Table 4. Omega 6 to omega 3 ratio in smoked fish products

Smoked product	Omega 6 / omega 3 ratio
Cold smoked salmon	$0.93 \pm 0.05^{a*}$
Hot smoked salmon	$3.10 \pm 0.13^{b*}$
Cold smoked herring	$0.19 \pm 0.02^{a*}$
Hot smoked herring	$0.64 \pm 0.08^{b*}$
Cold smoked mackerel	$0.21 \pm 0.034^{a*}$
Hot smoked mackerel	0.39 ± 0.04^{b}

Statistically significant values between groups. a – $P < 0.05$; b* – $P < 0.001$.

According to the data presented in Table 4, the most suitable n-6/n-3 ratio for the human diet was found in cold smoked salmon products.

It is important to note that the highest atherogenic index was detected in hot smoked herring, while the lowest in cold smoked mackerel products, and the difference between the groups was 2.8 times ($P < 0.05$).

This study results indicated (Table 5) that the thrombogenic index between all tested smoked fish product groups showed very similar values and no statistically significant differences were detected ($P > 0.05$).

The relationship between the quantities of PUFA, n-3 and n-6 FA were determined by calculating the correlation coefficients for each fish product. The produced data showed that the correlation between PUFA and the n-6/n-3 ratio of salmon products (raw, salted, smoked) was moderate negative ($r = –0.602$), between n-3 and the n-6/n-3 ratio it was negative strong ($r = –0.899$), and between n-6 and the ratio n-6/n-3, the relationship was moderate ($r = 0.639$).

Strong negative relationships were found in various processed herring products between PUFA and the n-6/n-3 ratio ($r = –0.83$), and strong positive between n-6 FA and the n-6/n-3 ratio ($r = 0.888$). A strong negative relationship was found between n-3 and the n-6/n-3 ratio ($r = –0.721$).

A negative moderate relationship was found between PUFA and the n-6/n-3 ratio ($r = –0.628$) in mackerel products, whereas a very weak correlation was noticed between n-6 and the n-6/n-3 ratio ($r = –0.038$). It is important to note that a very strong negative relationship was found between n-3 and the n-6/n-3 ratio ($r = –0.781$).

Discussion

The demand for healthy and functional foods in the world is steadily increasing. Fish products play an important role in human diet. It is important to note that a clear correlation exists between the expectation of a healthy life and the consumption of fish and sea food products (Sampels, 2015). Moreover, it is important to consider that fish products are rich in PUFA, especially n-3 and n-6 and their ratio (n-6/n-3) play the main the role in the human health (Ellulu et al., 2015; Pickova, 2009).

According to this study results, the highest amount of PUFA was detected in herring and mackerel fillet samples and mackerel products (salted, cold and hot smoked) in comparison with salmon samples. Moreover, FA profiles and quantity of PUFA in products depend on fish species and their quality is also affected by fish diet (Moini et al., 2012).

Our study data correlate with findings of other researchers who investigated mackerel (Orban et al., 2011) and salmon products (Gladyshev et al., 2009).

Contrary to the above, the tendency of significantly increasing PUFA values was determined in all tested cold smoked products in comparison with the samples obtained from raw material and other processed fish product groups. There are no similar data presented by other researchers. It is clear that cold smoking fish products had a significantly higher amount of n-3 in comparison with hot smoked products. This result can be related with high temperature (over 68°C), which has an influence on PUFA oxidation during the hot smoking process (Stolyhwo et al., 2006).

Omega 3 FA play a very important role in the prevention of human diseases associated with chronic inflammation. In molecular studies, omega-3 FA have direct effects in reducing the inflammatory state by reducing the level proinflammatory cytokines like interleukin -6 (IL-6) and tumour necrosis factor alpha, TNF-α, C reactive protein (CRP) and many other factors (Ellulu et al., 2015).

This study results showed that the highest quantity of n-3 fatty acids was found in herring and cold smoked fish products retailed in the Lithuanian market, whereas in farmed salmon products, this value was lower. These results can be explained by a different aquaculture (farmed) and wild marine fish nutrition. The n-3 quantity in fish and mammals mostly depends on the diet and on the ability to elongate and desaturate plant driven alfa linoleic acid to their longer C_{20} and C_{22} derivates (Ghioni et al., 1999). Feeding has an influence on the total fat content and fatty acids composition in all species of aquaculture fish. Salmon and rainbow trout, especially, get a lot of vegetable oils in their feed, such as sunflower, soybean, rapeseeds and linseeds to achieve intensive growth as well as faster lipid deposition during a short time period. Therefore, a high number of n-6 deposits in their fat can be detected due to diet. Contrary to the above, in marine fish the basic fatty acids content, cumulated in marine food chain, depends on marine phytoplankton (Jónasdóttir, 2019; Ruiz-Lopez et al., 2012). They can effectively synthesize LC PUFA

Table 5. Atherogenic (AI) and thrombogenic (TI) indexes in smoked fish products

Indices	Smoked fish products					
	Cold smoked Atlantic salmons	Hot smoked Atlantic salmon	Cold smoked herring	Hot smoked herring	Cold smoked mackerel	Hot smoked mackerel
AI	0.33	0.51	0.85*	0.82*	0.23*	0.30
TI	0.19	0.28	0.21	0.22	0.25	0.27

*Statistically significant values between groups ($P < 0.05$).

from ALA and LA using desaturation and elongation reactions.

More recently, a special focus was placed on the ratio n-6/n-3, because a very high intake of n-6 acids is less desirable due to excessive amounts of n-6 PUFA and very high n-6/n-3 ratio diets promoting the pathogenesis of many diseases. However, in some cardiovascular disease, cancer, inflammatory and autoimmune diseases, an increased level of omega-3 PUFA (a low n-6/n-3 ratio) exerts suppressive effect on illnesses associated with chronic inflammation (Simopulos, 2008).

This study results were in agreement with WHO recommendations as the most suitable for human health n-6/n-3 ratio was found in Atlantic salmon products and their values ranged from 0.70:1 in salted products up to 1.38:1. Similar results associated with salmon products were described by Strobel et al. (2012), although Regulska – Ilow et al. (2016) stated that ratio n-6/n-3 in raw mackerel was lower.

TFAI are created when liquid fish oil is hydrogenated; this is frequently done to increase their plasticity and chemical stability for subsequent food processing. TFAI also have been implicated in aetiology of various metabolic functional human disorders, related to cancer risk (Valenzuela & Morgado, 1999), and may provoke cardiovascular diseases (Dawczynski & Lorkowski, 2016).

According to this study results, the content of trans isomers in fish products was low and ranged from 0.11% in raw mackerel fillet up to 3.1% in cold smoked products. It is important to note that other researchers (Roe et al., 2013; Regulska – Ilow et al., 2013) found similar results in fish, presented in United Kingdom and Poland markets.

It is known that two processes, atherosclerosis and thrombosis, have influence on the coronary and heart diseases, including ischaemic heart disease (IHD). Moreover, the dietary fat consumed has influence on both of them. SFA with a chain length of 12, 14, 16 atoms have a cholesterol raising effect and thus are atherogenic (Keys et al., 1965; Bonamone & Gundy, 1988).

It is known that SFA with a chain length of 14, 16, 18 C are thrombogenic (Hornstra & Lussemberg, 1975). On the opposite, the MUFA and n-6 PUFA may reduce plasma cholesterol and low-density lipoprotein cholesterol (LDL–C) concentration (Gurr et al., 1989).

The atherogenic index is anti-atherogenic, inhibiting the aggregation of plague diminishing levels of some parts of components. The thrombogenic index shows the tendency to form clots in blood vessels. This is defined as the relationship between the thrombogenic saturated and anti-thrombogenic fatty acids. The atherogenic and thrombogenic indices, proposed by Ulbricht Southgate (1991), are related to the composite diet or a single food intake in prevention of atherosclerosis and platelets (Orban et al., 2011). However, other factors are important: low density lipoprotein (LDL), platelet activation factor (PAF), LDL oxidation, which may influence the inflammatory response to atherogenesis. Additionally, single fatty acids might have a harmful effect on human health due to atheroma and thrombus formation (Garaffo, 2011). According to our study results, the most favourable atherogenic (AI) and thrombogenic (AI) indices were found in most salmon products. These results are similar to the results described by other authors (Krešić et al., 2019), although our calculated AI and TI indices were slightly higher than the results presented in Fernandes et al.'s (2014) study about mackerel products.

Conclusions

The results of this study showed that a higher amount of PUFA ($P < 0.05$) was found in raw (fillets) and cold smoked fish products in comparison with heat-treated samples, retailed in the Lithuanian market. The most favourable FA composition for human health was detected in mackerel products, which had the highest content of n-3. Also, it is very important to note that a higher amount of n-3 ($P < 0.05$) was also found in raw (unprocessed) fish samples compared them with processed. Therefore, their n-6/n-3 ratio was also significantly lower. The most favourable atherogenic (AI – 0.13) and thrombogenic (TI – 0.17) indices for human health were detected in raw Atlantic salmon fillets, while slightly worse indices were calculated in cold-smoked mackerel (AI – 0.23, TI – 0.25) samples.

Conflict of interest

The authors declare no conflicts of interest.

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