Title: Effect Of Fish And Oil Nature On Frying Process And Nutritional Product Quality.

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ABSTRACT

The modifications on a lean fish (cod - *Gadus morhua*) and a fatty fish (farmed salmon - *Salmo salar*) after the application of pan-frying using two types of oil with different lipid profile (extra virgin olive oil and sunflower oil) was the aim of this study.

Fat content and total energetic value increased significantly after the frying process only in the lean fish, without relevant changes in the fatty fish. Extra virgin olive oil leaded to a higher fat absorption rate than sunflower oil in both fishes. Frying hardly affected the lipid profile of farmed salmon regardless the oil used, however it drastically changed in fried cod compared to raw cod. Omega-6/omega-3 ratio increased from 0.08 in raw cod to 1.01 and 6.63 in fried cod with olive oil and sunflower oil, respectively. In farmed salmon, the omega-6/omega-3 ratio was 0.38 (raw), and 0.39-0.58 in fried salmon. The amount of EPA+DHA slightly decreased with frying in salmon, and increased in cod. The type of oil have more influence in the nutritional fish quality for the lean fish compared to that of the fatty fish. The use of extra virgin olive oil was efficient to avoid a significant increase of the lipid oxidation intensity during frying in cod but not in salmon.

Practical application

Food modifies its composition and nutritional value with the application of cooking technologies. As most food table composition tables are based on raw food products, this paper contributes with interesting data on pan-fried fish

composition, which may improve the approach to achieve a real intake of healthy nutrients as omega 3 fatty acids.

KEYWORDS: Pan-frying, Fatty acids; Olive oil, Sunflower oil; Cod, Salmon.

INTRODUCTION

Gastronomy has always been considered an important tool to achieve an optimal diet. Among the most usual cooking technologies used to prepare food is the pan frying. This technology can significantly affect the fat intake, both the amount and the quality, and in consequence, the consumer's health.

A strong recommendation to increase the intake of fish, specially fatty fish, is evidenced (WHO 2003), due to the beneficial effects attributed to the long chain polyunsaturated omega 3 fatty acids (Erkkilä and others 2004; Ruxton and others 2004; Simopoulos 2006; Chrysohoou and others 2007).

Several mechanisms could explain changes occurred in the fish lipid profile during the culinary process: absorption of culinary fat in the fish, moisture loss of the food, leaching of fat-soluble molecules out of the food and oxidation reactions with free radicals generated in the hot culinary fat (Little and others 2000). The two first mechanisms result in an increase in the amount of fatty acids, the other ones in their decrease.

Different studies evaluate the effect of deep-fat frying in the composition and nutritional properties of fish (Echarte and others 2001; García-Arias and others 2003; Gladyshev and others 2007; Weber and others 2008) and demonstrate that an exchange of lipid compounds between the frying bath and the food takes place. The intensity of these changes is determined by the nature of the fat or oil and the manipulation of the food. Furthermore, *in vitro* and *in vivo* studies have evidenced that deep-fat frying alters the bioactivity of the fish lipid fractions, as it reduces its platelet aggregation capacity (decreasing then the possibilities of developing atherosclerotic plaques), affecting their protective role with respect to

cardiovascular diseases (Nomikos and others 2006) and also that there are interactions between fried fish protein and olive oil that seemed to result in digestion products that enhance iron absorption (Seiquer and others 2002).

Pan-frying is a common culinary preparation of fish, resulting in significant changes of major and minor food constituents, making necessary the analyses of cooked foods in order to estimate nutrient intakes and health risks (Kalogeropoulos and others 2004). Compared to the current scientific knowledge on deep-fat frying, less papers deal with the application of pan-frying on fish (Al-Saghir and others 2004; Sioen and others 2006; Kalogeropoulos and others 2007).

The objective of this paper was to contribute to increase the knowledge on cooked fish composition data considering different variables. In particular, this work analyses the modifications on lean fish and fatty fish (cod and farmed salmon) after the application of pan-frying using two types of oil with different lipid profile, extra virgin olive oil and sunflower oil. Changes in the composition and lipid profile were evaluated, and also the oxidation process induced by this cooking technology was studied.

EXPERIMENTAL

Samples

Fillets of cod (*Gadus morhua*) and farmed salmon (*Salmo salar*) were purchased at the supermarket and cut into slices with the same form and thickness (1.5cm on average). They had been recently caught from the open sea and from the farm, respectively,(< 48h) and maintained on chopped ice, prior to being sampled. Fish fillets were vacuum-packed and stored at -30ºC (no more than 30 days). For the analysis of each type of fish the frozen samples were thawed at 4ºC, during 24 hours, and then they were randomly chosen for each treatment. The fillets were then divided in three batches: one batch of fillets was analyzed in raw, a second one was analyzed after frying with extra virgin olive oil and a third one after frying with sunflower oil. Four fillets were selected per batch and analysis was performed after their homogenization. As culinary fat, commercial extra virgin olive oil and sunflower oil were used. Lipid profile of extra virgin olive oil and sunflower oil were analyzed and they are shown in table 1 (g/100g fatty acids).

Cooking procedure

The fillets were fried in a frying pan (25cm diameter) for 4 min (2 min for each side) using an oil/food ratio of 10 ml oil/100 g sample (for each fillet the exact volume of fresh oil was calculated). The oil temperature prior to start frying was 180ºC, controlled by a specific digital thermometer (Fluka 51). During frying the core temperature of the fillets was recorded (T=65ºC for salmon and T=85ºC for cod). After frying, the fish fillets were drained gently on stainless steel grills and allowed to be air cooled.

Chemical analysis

Moisture, protein, fat and ash were determined according to the Association of Official Analytical Chemists method (AOAC) (AOAC 2002a, 2002b, 2002c, 2002d), respectively. A chloroform:methanol mixture was used for the extraction of lipids (Folch and others 1957). Fatty acids were determined in the oils used for frying and in the fish lipid extracts by gas chromatography. Boron trifluoride/methanol was used for the preparation of fatty acid methyl esters, which were finally solved in hexane (AOAC 2002e). A Perkin-Elmer Clarus 500 gas chromatograph (PE, Shelton, CT, USA) fitted with a capillary column SP^{TM}-2560 (100m x 0.25mm x 0.2μm) and flame ionization detection was used. The temperature of the injection port was 250ºC and of the detector was 260ºC. The oven temperature was programmed at 175ºC during 10min and increased to 200ºC at a rate of 10ºC/min, then increased to 220ºC at a rate of 4ºC/min, which was held for 15min. The carrier gas was hydrogen, and the pressure was 20.5psi. Split ratio was 120:1. The identification of the fatty acid methyl esters was done by comparison of the retention times of the peaks in the sample with those of standard pure compounds (Sigma, St. Louis, MO, USA) and by spiking the sample with each standard compound individually. The quantification of individual fatty acids was based on the internal standard method, using heptadecanoic acid methyl ester (Sigma, St. Louis, MO, USA). 1ml of the internal standard solution (7mg/ml) was added to 1ml of the fatty acid methyl ester hexane solution, just previously to be injected.

Cholesterol content was analyzed by gas chromatography, previous extraction with hexane (Kovacs and others 1979). A Perkin-Elmer Autosystem XL gas chromatograph equipped with an HP1 column (30m x 0.25mm x 0.1μm) was used. The oven temperature was 265ºC. The temperature of both the injection port

and detector was 285ºC. Cholesterol was identified by comparing its retention time with that of a standard (Sigma, ST. Louis, MO, USA) and quantification was done by using pure cholestane (Sigma, St. Louis, MO, USA) as an internal standard, which was added to the sample as a solution (2mg/ml), previously to the extraction procedure. A Perkin-Elmer Turbochrom programme was used for quantification.

Lipid oxidation (TBARs value) was determined according to Tarladgis and others (1960) with modifications by Tarladgis and others (1964). Results are shown in mg malonaldehyde/kg sample (ppm).

Statistical analysis

Each cooking procedure was done in duplicate, and the analytical parameters were determined four times in each sample. Data presented in tables are the mean, standard deviation and coefficient of variation for each parameter and type of sample.

For each type of fish, a one-way ANOVA and Tukey´s b post hoc were used to analyse statistical differences among the three studied conditions (raw-freeze thawed fish, fried with extra virgin olive oil, and fried with sunflower oil). Principal component analysis (PCA) was also carried out in order to evaluate the influence of the analysed parameters on the total variability found. Varimax rotation was applied in order to maximise the variance in each loading vector. Statistical analysis was performed using SPSS software for Windows (release 15.0).

RESULTS & DISCUSSION

General composition

Tables 2 and 3 show general composition, cholesterol content and Total Energetic Value (TEV) of farmed salmon and cod respectively, analyzed in raw and after being fried in extra virgin olive oil and in sunflower oil.

Cooking procedures can significantly affect the moisture losses of fish, depending on the temperature reached. Weber and others (2008) comparing 7 cooking methods (including deep-fat frying with different oils) applied to silver catfish fillets (*Rhamdia quelen*, a lean fish) found that the highest losses corresponded to the frying procedures. The moisture losses found in every sample in this work were also significant, reaching percentages of 9% moisture loss in the case of salmon and 7% in the case of cod, regardless the oil used.

Simultaneously to the reduction of moisture, an exchange of fat between the food and the fat takes place when frying is applied, affecting differently depending on the type of fish. Expressed on a dry matter basis, the increase of the fat content was 11.6% and 16.4% for cod fried with sunflower and extra virgin olive oil, respectively. On the contrary, in the case of farmed salmon, decreases of 2.1% and 8.9% of fat content were observed after frying with olive and sunflower oil, respectively. As it is shown in the tables, when these results are expressed on a product (ready to eat) basis, fried cod showed an increase of fat with both culinary oils, especially with olive oil, compared to raw cod. However, the fat content of farmed salmon hardly changed.

Modification of moisture and fat content led to changes in the protein values and in TEV. Protein increased a 35% on average when cooking both types of fish with sunflower oil, and around a 25% when frying with olive oil. TEV increased when salmon was fried with olive oil, but it was not modified with sunflower oil. In the

case of cod, TEV increased significantly with both culinary oils (around a 75%), from 60.90 to 106.53 kcal/100 g product with olive oil and to 109.09 kcal/100 g product with sunflower oil. Cholesterol content was only affected in the case of cod fried with olive oil (from 69mg/100g to 52mg/100g); no statistically significant changes were found for salmon samples, although a trend to a decrease during frying with olive oil was noticed.

Lipid profile

The fat content of raw fish can influence fat exchanges between the culinary fat and the fish (Sanchez-Muniz and others 1992). Sioen and others (2006) analysing changes in the fatty acids content of both cod and salmon as a consequence of pan-frying with margarine and olive oil found a significant increase in the case of cod and a decreasing trend in the case of salmon. In this work, similar results were found: pan-frying with both oils significantly increased the total fat content and the three fatty acids fractions in the case of the lean fish (cod), whereas the total fat content and the different fatty acids of salmon were hardly modified after frying.

Fatty acid profiles of farmed salmon, raw and fried with olive oil and sunflower oil (g/100 g fatty acids) were shown in table 4. In raw salmon, the most abundant fatty acids were oleic (27.59%), palmitic (15.09%), DHA (10.01%), and linoleic (7.98%). Frying with olive oil, slightly increased oleic acid to 30.4% whereas frying with sunflower oil increased linoleic acid up to 11.6%. No quantitatively relevant decreases were found in any particular fatty acid, being all of them similarly affected.

A totally different profile of raw cod samples was found compared to farmed salmon (Table 6). The most abundant fatty acids in raw cod were DHA (33.01%), followed by palmitic (19.96%), EPA (14.56%) and oleic acids (9.59%). This profile significantly changed with frying. Oleic and linoleic became more abundant with frying, achieving a 65.12% and a 6.46% respectively when using olive oil, and reaching a 45.40% and 31.58% when using sunflower oil. Significant decreases were found during frying with both oils for palmitic, α-linolenic, EPA and DHA. In fact, EPA decreased from 14.56% to 1.76% in samples fried with olive oil and to 2.22% in samples fried with sunflower oil; DHA decreased from 35.01% to 4.03% and 4.28%, respectively.

Summatories (g/100 g product) and ratios with nutritional interest of salmon and cod before and after frying were shown in tables 4 and 6. PUFA+MUFA/SFA proportion was similar before (3.33) and after (3.50) frying salmon. However, it increased significantly when frying cod (from 3.04 to 4.93 when frying with olive oil and to 6.29 when frying with sunflower oil). Bakar and others (2008) comparing the effect of different cooking methods on lipid characteristics of other type of lean fish (mackerel, *Scomberomorous guttatus*), observed that frying resulted in the change of the SFA/PUFA ratio more than other cooking methods.

In relation to the EPA+DHA content, although there is a decrease with pan-frying in the case of farmed salmon, the dietary supply was much higher regardless the type of oil used, than that of the lean fish. Taking into account that a usual portion of fish is around 150g (Muñoz and others 2004) the supply of the mixture of EPA + DHA when the fishes were cooked with olive oil was 6.37g for salmon and 0.330g for cod, and when they were cooked with sunflower oil it was 5.65g for

salmon and 0.315g for cod. So, the recommended intake for the sum of EPA + DHA, that it is established in 0.650g/day (Simopoulos and others, 1999), would be widely covered by a portion of fried salmon and in a 50% with a portion of fried cod.

The omega-6/omega-3 ratio is also a very important index from a public health standpoint. It is recommended not to be higher than 4 to 1, because an alteration of this balance increases the incidence of chronic and cardiovascular diseases (Simopoulos 2002). The only samples in which no increment in the omega-6/omega-3 ratio was detected were those of salmon fried with virgin extra olive oil (0.39). A value of 0.38 was detected in raw samples and 0.58 in salmon fried with sunflower oil. The increases in cod samples were quite high, especially when frying with sunflower oil (from 0.08 in raw cod to 1.01 in cod fried with extra virgin olive oil and to 6.63 in cod fried with sunflower oil). Comparing these results with those obtained by Sioen and others (2006) it can be observed similar results for salmon when the oil used was olive oil, extra virgin oil and margarine, but higher omega-6/omega-3 ratios when sunflower oil is used. In the case of cod the results differed significantly, with higher increases when frying with margarine and sunflower oil.

Lipid oxidation

A clear influence of both the type of fish and the type of oil was observed in the oxidation status of the lipid fraction. Higher TBARS values were detected in raw farmed salmon samples than in raw cod samples (table 8), although all of them were below 0.75mg of malonic aldehyde/Kg product. Weber and others (2008) did not observe significant differences in the TBARS value of deep-fried fillets of

silver catfish when compared with the raw fillets. Those authors explained this fact by the lost of the MDA eventually formed by dissolution in the frying oil or due to the formation of adducts with proteins. In our work, higher increases of TBARS for both types of fish were observed when sunflower oil was used for frying, probably due to the more polyunsaturated profile of that oil. It is known that lipid oxidation susceptibility increases with the number of unsaturations in the molecule. Gladyshev and others (2006) hypothesize that in species of *Salmonidae* family there are high levels of natural antioxidants in their red colored flesh, which prevent PUFAs oxidation during heat treatments. This hypothesis could explain why, despite of the high amount of PUFAs in salmon fried with sunflower oil, the TBARS value only increased 2.5 fold, whereas a 8 fold increase was detected for cod. The use of extra virgin olive oil only increased the TBARS value in salmon, with a higher fat content than cod, where the natural antioxidants of extra virgin olive oil could have been effective.

Figure 1 shows the distribution of the score vectors for the different samples as a consequence of the multivariable statistical analysis (Principal Components Analysis) carried out with the results obtained for the analysis of the lipid fraction, including also TBARS data. Also the loading vector for these parameters were shown. The two main components (PC 1 and PC 2) explained a 81.5 % of the variability of the variables under study. Raw and pan-fried farmed salmon samples were not clearly differentiated, whereas the different cod samples (raw, fried with extra virgin olive oil, and fried with sunflower oil) seemed to be influenced and separated by their different lipid profile. These results showed that the relative differences due to the frying process were much higher in the low fat fish than in the high fat one. The type of oil will consequently have more

influence in the nutritional fish quality for the lean fish compared to that of the fatty fish. This fact was a consequence of the higher absorption of fat in the case of cod.

In conclusion, this paper contributes with original results concerning variables affecting composition of cooked fish, needed to achieve a closer approach to real dietary nutrients intake.

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Table 1. Fatty acids profile of Extra virgin Olive oil and Sunflower oil (g/100 g fatty acids).

Fatty acid	Extra virgin Olive oil	Sunflower oil
Myristic C14:0	nd	0.07±0.00
Palmitic C16:0	12.75±0.01	6.30±0.02
t-Palmitoleic C16:1 t-7	0.12±0.00	0.04±0.00
Palmitoleic C16:1	1.02±0.00	0.13±0.00
Stearic C18:0	2.26±0.01	4.23±0.01
Elaidic C18:1 t-9	0.10±0.00	0.11±0.00
Oleic C18:1 ω-9	72.05±0.06	34.53±0.05
Vaccenic C18:1 ω-7	2.70±0.01	0.77±0.01
Linoleic C18:2 ω-6	7.30±0.01	52.11±0.11
α-Linolenic C18:3 ω-3	0.69±0.00	0.05±0.01
Behenic C22:0	0.06±0.00	0.65±0.00
Arachidonic C20:4 ω-6	0.40±0.03	0.04±0.00
Eicosapentaenoic C20:5 ω-3	nd	0.22±0.02

Results as mean± standard deviation. n.d: not detected.

Table 2. General composition, cholesterol content and Total Energetic Value (TEV) in raw farmed salmon, and farmed salmon fried in Olive oil and Sunflower oil

General composition	Raw Salmon	Salmon Fried in Extra virgin Olive oil	Salmon Fried in Sunflower oil
Moisture (%)	55.50±0.21c (0.38%)*	49.37±0.70a (0.70%)*	51.59±0.35b (0.67%)*
Protein (%)	17.62±0.41a (2.34%)*	21.87±0.27b (1.23%)*	23.63±0.36c (1.51%)*
Fat (%)	26.17±0.29b (1.11%)*	28.74±0.98c (3.41%)*	24.14±0.36a (1.49)*
Ash (%)	1.13±0.01a (0.99%)*	1.38±0.04a (0.04%)*	1.68±0.22b (12.84%)*
TEV (Kcal/100 g product)	306±3.26a (1.06%)*	346±9,46b (2.73%)*	311±4.58a (1.46%)*
Cholesterol (mg/100 g product)	89.13±6.96a (7.90%)*	77.21±10.29a (12.76%)*	94.83±7.24a (7.79%)*

Results as mean± standard deviation (SD). Different letters in the same raw denote significant differences ($p<0.05$). *Coefficient of variation = SD/mean x100.

Table 3. General composition, cholesterol content and Total Energetic Value (TEV) in raw cod and cod fried in Extra virgin Olive oil and Sunflower oil

General composition	Raw	Fried Extra virgin Olive oil	Fried Sunflower oil
Moisture (%)	83.55±0.37c (0.38%)*	79.90±1.17b (1.46%)*	75.44±0.22a (0.29%)*
Protein (%)	14.60±0.36a (2.14%)*	18.48±0.05b (0.27%)*	19.94±0.24c (1.22%)*
Fat (%)	0.28±0.03a (10.81%)*	3.63±0.08c (2.07%)*	3.26±0.02b (0.71%)*
Ash (%)	1.50±0.04a (2.15%)*	1.66±0.02a (1.48%)*	1.72±0.19a (11.19%)*
TEV (Kcal/100g product)	60.90±1.71a (2.80 %)*	106.53±0.81b (0.76 %)*	109.09±0.96c (0.88 %)*
Cholesterol (mg/100g product)	69.70±2.39b (3.44 %)*	52.43±5.49a (10.48 %)*	64.50±2.67b (4.14 %)*

Results as mean± standard deviation (SD). Different letters in the same raw denote significant differences ($p<0.05$). *Coefficient of variation = SD/mean x100

Table 4. Fatty acids profile of raw farmed salmon, farmed salmon fried with Extra virgin Olive oil and Sunflower oil (g/100 g fatty acids)

Fatty acid	Raw Salmon	Salmon Fried in Extra virgin Olive oil	Salmon Fried in Sunflower oil
Lauric C12:0	0.08±0.00a	0.08±0.00a	0.07±0,00a
Myristic C14:0	4.93±0.04b	4.52±0.02a	4.51±0.02a
Palmitic C16:0	15.09±0.01c	14.71±0.01b	14.31±0.01a
t-Palmitoleic C16:1 t-7	0.18±0.01b	0.16±0.00a	0.16±0.00a
Palmitoleic C16:1	5.30±0.04c	4.98±0.02b	4.85±0.01a
Stearic C18:0	2.76±0.01b	2.67±0.01a	2.90±0.01c
Elaidic C18:1 t-9	0.07±0.01a	0.07±0.01a	0.08±0.03a
Oleic C18:1 ω-9	27.59±0.03a	30.37±0.08c	28.04±0.05b
Vaccenic C18:1 ω-7	3.34±0.01c	3.31±0.01b	3.10±0.01a
t-Linoleic C18:2 t-9 t-12	0.03±0.00a	0.07±0.00b	0.03±0.00a
c-t linoleic C18:2 c-9 t-12	0.10±0.00a	0.10±0.01a	0.11±0.00b
Linoleic C18:2 ω-6	7.98±0.01a	7.98±0.01a	11.63±0.04b
Arachidic C20:0	0.08±0.00b	0.06±0.00a	0.10±0.01c
γ-Linolenic C18:3 ω-6	0.08±0.00b	0.06±0.00a	0.08±0.00b
Eicosenoic C20:1 ω-9	6.91±0.02c	6.32±0.02b	6.25±0.04a
α-Linolenic C18:3 ω-3	3.17±0.00c	3.06±0.01b	2.92±0.01a
Behenic C22:0	0.03±0.00a	0.03±0.00a	0.08±0.00b
Brassidic C20:1 t-9	0.18±0.00c	0.15±0.00a	0.16±0.00b
Erucic C22:1 ω-9	0.76±0.00b	0.70±0.00a	0.69±0.01a
Eicosatrienoic C20:3 ω-3	0.15±0.00a	0.14±0.00a	0.14±0.00a
Arachidonic C20:4 ω-6	0.46±0.00a	0.44±0.00a	0.43±0.00a
Eicosapentaenoic C20:5 ω-3	6.64±0.02c	6.50±0.02b	6.21±0.05a
Nervonic C24:1	0.60±0.01b	0.51±0.01a	0.54±0.00a
Docosatrienoic C22:3 ω-3	0.01±0.00a	n.d.	n.d.
Docosapentaenoic C22:5 ω-6	0.36±0.02b	0.34±0.01a	0.32±0.02a
Docosapentaenoic C22:5 ω-3	3.13±0.00c	2.91±0.01b	2.88±0.01a
Docosahexaenoic C22:6 ω-3	10.01±0.03c	9.76±0.02b	9.41±0.02a

Results as mean± standard deviation. Different letters in the same raw denote significant differences ($p<0.05$). n.d: not detected.

Table 5. Summatories and ratios with nutritional interests of raw farmed salmon and fried with Extra virgin Olive oil and Sunflower oil. (g/100 g product)

	Raw Salmon	Salmon Fried in Extra virgin Olive oil	Salmon Fried in Sunflower oil
Σ SFA	6.01±0.01c	5.78±0.01b	5.30±0.00a
Σ MUFA	11.65±0.01b	12.09±0.02c	10.49±0.02a
Σ PUFA	8.37±0.01c	8.17±0.02a	8.21±0.03b
Σ EPA + DHA	4.36±0.01c	4.25±0.02b	3.77±0.02a
ω-6/ ω-3	0.38±0.00a	0.39,0.00a	0.58±0.00b
PUFA/SFA	1.39±0.00a	1.41±0.00b	1.55±0.00c
PUFA+MUFA/SFA	3.33±0.00a	3.50±0.00b	3.53±0.00c
Trans	0.15±0.00b	0.14±0.00b	0.13±0.01a

Results as mean± standard deviation. Different letters in the same raw denote significant differences ($p<0.05$). SFA: Saturated Fatty Acids; MUFA: Monounsaturated Fatty Acid; PUFA: Polyunsaturated Fatty Acids.

Table 6. Fatty acids profile of raw cod, cod fried with Extra virgin Olive oil and Sunflower oil. (g/100g fatty acids)

Fatty acid	Raw Cod	Cod Fried in Extra virgin Olive oil	Cod Fried in Sunflower oil
Lauric C12:0	0.05±0.01a	0.02±0.00a	0.03±0.02a
Myristic C14:0	0.83±0.01c	0.10± 0.00a	0.18±0.00b
Palmitic C16:0	19.96±0.09c	13.92±0.07b	8.46±0.05a
t-Palmitoleic C16:1 t-7	n.d.	n.d.	n.d.
Palmitoleic C16:1	1.24±0.01c	1.04±0.01b	0.27±0.00a
Stearic C18:0	3.81±0.01b	2.52±0.01a	4.31±0.03c
Elaidic C18:1 t-9	0.53±0.01b	0.09±0.01a	0.07±0.01a
Oleic C18:1 ω-9	9.59±0.01a	65.12±0.03c	31.58±0.10b
Vaccenic C18:1 ω-7	3.31±0.03c	2.86±0.01b	1.21±0.01a
t-Linoleic C18:2 t-9 t-12	n.d.	0.05±0.00a	0.10±0.09a
c-t linoleic C18:2 c-9 t-12	n.d.	0.03±0.00a	0.23±0.03b
Linoleic C18:2 ω-6	2.87±0.01a	6.46±0.01b	45.40±0.15c
Arachidic C20:0	n.d.	0.19±0.01a	0.11±0.00a
γ-Linolenic C18:3 ω-6	n.d.	n.d.	n.d.
Eicosenoic C20:1 ω-9	1.51±0.01c	0.37±0.01b	0.27±0.00a
α-Linolenic C18:3 ω-3	6.12±0.02c	0.62±0.00b	0.10±0.01a
Behenic C22:0	n.d.	0.06±0.00a	0.58±0.01b
Brassidic C20:1 t-9	n.d.	0.03±0.00a	0.03±0.00a
Erucic C22:1 ω-9	n.d.	0.21±0.00a	0.26±0.00a
Eicosatrienoic C20:3 ω-3	n.d.	n.d.	n.d.
Arachidonic C20:4 ω-6	1.59±0.01c	0.26±0.00b	0.04±0.00a
Eicosapentaenoic C20:5 ω-3	14.56±0.03c	1.76±0.02a	2.22±0.18b
Nervonic C24:1	n.d.	n.d.	n.d.
Docosatrienoic C22:3 ω-3	n.d.	n.d.	n.d.
Docosapentaenoic C22:5 ω-6	n.d.	n.d.	n.d.
Docosapentaenoic C22:5 ω-3	1.03±0.03b	0.25±0.01a	0.27±0.00a
Docosahexaenoic C22:6 ω-3	33.01±0.21b	4.03±0.05a	4.28±0.12a

Results as mean± standard deviation. Different letters in the same raw denote significant differences ($p<0.05$). n.d.: not detected

Table 7. Summatories and ratios with nutritional interests of raw cod and fried with Extra virgin Olive oil and Sunflower oil. (g/100 g product)

	Raw Cod	Cod Fried in Extra virgin Olive oil	Cod Fried in Sunflower oil
Σ SFA	0.07±0.00a	0.61±0.00c	0.45±0.00b
Σ MUFA	0.04±0.00a	2.53±0.01c	1.10±0.00b
Σ PUFA	0.17±0.00a	0.49±0.01b	1.71 0.01c
Σ EPA + DHA	0.13±0.00a	0.22±0.01b	0.21±0.01b
ω-6/ ω-3	0.08±0.00a	1.01±0.03b	6.63±0.18c
PUFA/SFA	2.40±0.02b	0.80±0.01a	3.83±0.04c
PUFA+MUFA/SFA	3.04±0.02a	4.93±0.02b	6.29±0.05c
Trans	0.00±0.00a	0.01±0.00a	0.01±0.00a

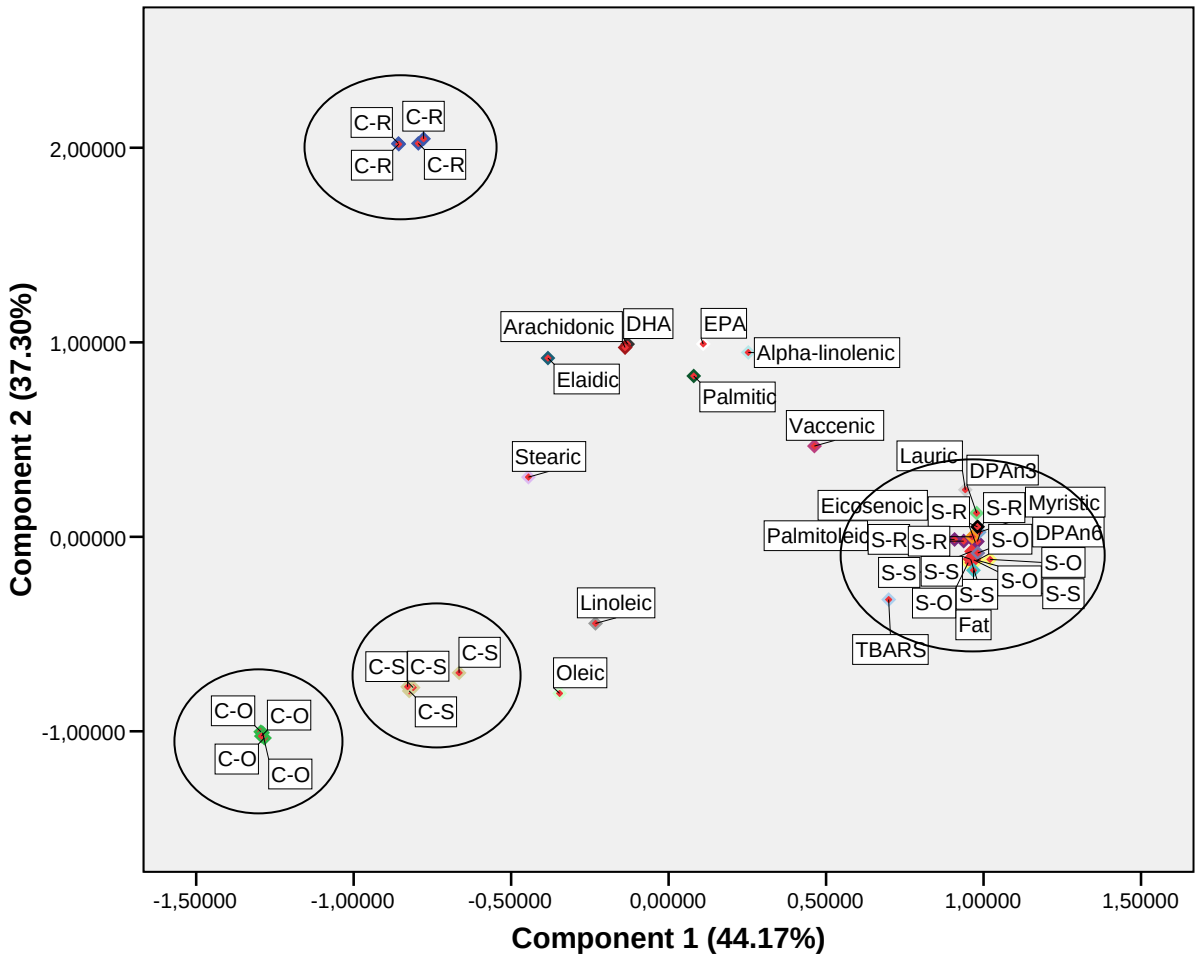
Results as mean± standard deviation. Different letters in the same raw denote significant differences ($p<0.05$). SFA: Saturated Fatty Acids; MUFA: Monounsaturated Fatty Acid; PUFA: Polyunsaturated Fatty Acids.

Table 8. Thiobarbituric acid values (TBARS values: mg of malonic aldehyde/Kg product) for salmon and cod in raw and after frying with Extra virgin Olive oil and Sunflower oil.

		Raw	Fried in Extra virgin Olive oil	Fried in Sunflower oil
TBARs values	**Salmon**	0.28±0.10a (6.11%)*	0.60±0.05b (8.67%)*	0.73±0.05c (7.03%)*
	Cod	0.06±0.01a (16.7 %)*	0.05±0.00a (3.35 %)*	0.53±0.02b (2.76 %)*

Results as mean± standard deviation (SD). Different letters in the same raw denote significant differences ($p<0.05$). *Coefficient of variation = SD/mean x100

Figure 1. Loading plot of lipid fraction parameters and representation of the six types of samples according to the Varimax rotated matrix in Principal component analysis (PCA).



C-R: Raw Cod; C-O: Cod fried in Extra virgin Olive oil; C-S: Cod fried in sunflower oil; S-R: Raw Farmed Salmon; S-O: Farmed Salmon fried in Extra virgin Olive oil; S-S: Farmed Salmon fried in sunflower oil