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Effects of origin and season on the lipids and sensory quality of European whitefish (*Coregonus lavaretus*)

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ABSTRACT

The effect of variation in origin and season on the lipids and sensory quality of European whitefish (*Coregonus lavaretus*) was studied. The proportion of docosahexaenoic acid (22:6$n-3$) of the total phospholipid fatty acids in fillets was considerably higher in spring compared with autumn. Farmed fish contained 3–4 times more lipids than wild fish. Combined, the fillets of farmed fish contained 2–3 times more eicosapentaenoic acid (20:5$n-3$) and docosahexaenoic acid than the fillets of wild fish. Contents of vitamin D were high both in farmed and wild fish. Aroma of raw farmed whitefish was less algae-like than wild one. Raw farmed whitefish was harder, less springy, and lighter in flesh color than wild whitefish. Cooked, farmed fish had slightly stronger flavor than wild fish. There was no significant difference in pleasantness between whitefish of different origin in any of the evaluated characteristics. Both farmed and wild European whitefish caught in autumn and spring proved to have a high content of $n-3$ fatty acids and vitamin D, and hence they serve as a good source of nutritionally important lipids.

1. Introduction

European whitefish (*Coregonus lavaretus*) farming is a rising industry in Finnish aquaculture. Currently, domestic supply from the farms surpasses the supply from wild catches (in 2014, 900 and 700 tons, respectively). The market value and quality characteristics of the whitefish of different origin (aquaculture or wild) vary. Thus, the recognition of specific characteristics of fish according to their origin is crucial in order to allocate distinct raw material to suitable processes, which ensures the supply of high quality end products of appropriate value.

In northern latitudes, seasonality constrains conditions for fish farming and harvesting. Many parameters can be maintained stable for farmed fish, whereby stable quality can be expected. Still, major production conditions in the sea cages follow the seasonality like conditions in the wild. e.g., the fish spend long winters mostly fasting, which is a specific state of metabolism. Previously, seasonal variation in fish chemical characteristics has been studied e.g., in Atlantic cod (Hemre et al., 2004), Atlantic halibut (Haugen et al., 2006; Olsson, Olsen, Carlehog, & Ofstad, 2003), gilthead (Senso, Suarez, Ruiz-Cara, & Garcia-Gallego, 2007) and yellow sea bream (Hwang, Jin, & Lim, 2014), European perch (Mairesse, Thomas, Gardeur, & Brun-Bellut, 2006), and common carp (Yeganeh, Shabanpour, Hosseini, Imanpour, & Shabani, 2012). Differences in chemical and sensory quality between wild and farmed fish has been indicated e.g., in Atlantic salmon (Farmer, McConnell, & Kilpatrick, 2000), Atlantic halibut (Olsson et al., 2003), European sea bass (Bell et al., 2007), yellow perch (Gonzalez et al., 2006), common carp (Yeganeh et al., 2012), rainbow trout (Fallah, Saei-Dehkordi, & Nematollahi, 2011), and gilthead sea bream (Grigorakis, 2007; Lenas, Triantafillou, Chatziantoniou, & Nathanailides, 2011). However, since the conditions in the coastal areas and archipelago of Southwest Finland in the Baltic Sea – the prime production area – are unique, many conclusions on the effect of seasonality and origin on fish quality cannot be drawn based on the earlier studies.

Aim of the present study was to investigate the effect of variation in terms of origin and season on the quality of European whitefish. The origin-specific effects on the lipid quality were studied both in autumn and spring in fish readily available in the market. Fat and fat-soluble vitamin content and composition were

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analyzed in the study, and sensory quality was determined by using a trained panel as well as by consumer testing.

2. Materials and methods

2.1. Chemicals and reagents

Triheptadecanoin and 1,2-dinonadecanoyl-*sn*-glycero-3-phosphocholine were purchased from Larodan Fine Chemicals AB (Malmö, Sweden). Potassium chloride (p.a. grade) was purchased from Merck KGaA (Darmstadt, Germany), boron trifluoride (~10% in methanol, p.a.) from Fluka (Buchs, Switzerland), and potassium hydroxide (p.a.) and ascorbic acid (p.a.) from J.T. Baker (Deventer, Netherlands). Fatty acid methyl ester mixture (68D) was obtained from Nu-Chek Prep, Inc. (Elysian, MN), *dl*-tocol from Tama Seikagaku Co., Ltd. (Tokyo, Japan), and tocopherol and tocotrienol mixtures from Calbiochem (Darmstadt, Germany). Ergocalciferol (vitamin D_2) and cholecalciferol (vitamin D_3) were purchased from Sigma (St. Louis, MO). Ethanol (technical grade) was obtained from Alko (Helsinki, Finland). All other solvents were of chromatography or analytical grade and were purchased from local suppliers.

2.2. Experimental fish and sampling

European whitefish grown in brackish sea water cages were obtained from local fish farm (Kalastusyhtymä Valtanen Ltd., Luvia, Finland, 61° N) in October and again in April. Whitefish was reportedly fed on commercial feeds with typical total fat content between 26% and 30% and fish oil content of approximately 20%. Fish were slaughtered in farm by industrial practices. Fish were gutted, bled and transferred on ice to a commercial filleting plant where they were processed (Kalaset Ltd., Uusikaupunki, Finland). Simultaneously, wild fish were caught from the Gulf of Bothnia (63–64° N in October and 61° N in April) by a local fisherman and delivered by public transportation to the same plant. One to two days after the slaughter, all fish were filleted and transferred on ice for analyses. Suppliers were requested for fish of size between 600 and 800 g. However, due to availability, sizes varied and exact weights were not determined until as fillets. Five fish from both origins were sampled both in October and in April.

2.3. Lipid extraction

Lipids were extracted from skinned fillet homogenates (two separate samples from each fillet) with chloroform/methanol (2:1, v/v). The procedures were made protected from light. Briefly, to 2.5–3.5 g of homogenate, 50 μL of *dl*-tocol in hexane (1 mg/mL) was added as an internal standard. The solvent was evaporated to dryness. A 20 mL amount of methanol was added and the mixture was homogenized with Ultra Turrax T25 homogenizer (Janke and Kunkel – IKA Labortechnik, Staufen, Germany) at 8000 rpm for 2 min. A 40 mL amount of chloroform was added and the mixture was homogenized again (8000 rpm, 2 min). The sample was filtrated in vacuum. A 60 mL amount of chloroform–methanol (2:1, v/v) was added to the residue which was subsequently homogenized at 8000 rpm for 3 min and filtrated. Containers and the blade of the homogenizer were flushed with 30 mL of chloroform/methanol (2:1, v/v) and the extract was filtrated. All the filtrates were combined. To the combined filtrate, 45 mL of 0.9% (w/v) potassium chloride solution was added. After mixing, the upper phase was removed. The lower phase was washed with 45 mL of 0.9% potassium chloride (w/v)/methanol (1:1, v/v). The lower phase was collected and evaporated to dryness in rotary evaporator. The sample was weighed and dissolved in 2 mL of chloroform. The extracts of duplicate samples were combined.

2.4. Vitamin E analysis

Two 1.0 mL aliquots (duplicate samples) of the combined lipid extract solution were filtered (duplicate samples) through 0.45 μm syringe filters (Spartan 13/0.45 RC, Whatman GmbH, Dassel, Germany) and evaporated to dryness with nitrogen. Chloroform was added so that the lipid concentration was 200–300 mg/mL. Tocopherols and tocotrienols were determined by high-performance liquid chromatography (HPLC) with fluorescence detection (Piironen, 1986). A 20 μL amount of sample was injected onto LichroCART Supespher Si 60 column (250 mm × 4.0 mm; Merck KGaA, Darmstadt, Germany) equipped with a LichroCART Superspher Si 60 pre-column (4.0 mm × 4.0 mm; 5 μm; Merck KGaA). A binary solvent gradient consisted of (A) hexane, and (B) di-isopropyl ether (dried and filtered). The gradient program was as follows: initial A/B (92:8, v/v), held isocratic for 5 min; linear from 5 to 30 min to A/B (83:17, v/v); held isocratic from 30 to 35 min; linear from 35 to 40 min to A/B (92:8); held isocratic until equilibrated. The flow rate was 1.6 mL/min and the column temperature was 30 °C. The fluorescence was measured at 325 nm using a Shimadzu RF-530 (Shimadzu Co., Kyoto, Japan) fluorescence detector with an excitation wavelength set at 290 nm. For quantification, the concentrations of the standard solutions were verified with a spectrophotometer (UV-2401PC, Shimadzu, Kyoto, Japan).

2.5. Separation of lipid classes

An aliquot of the combined lipid extract corresponding to 0.3 mg of lipids was transferred into two separate glass tubes (duplicate samples). A 50 μL amount of each internal standard (1 mg/mL chloroform of triheptadecanoin and 0.1 mg/mL chloroform of 1,2-dinonadecanoyl-*sn*-glycero-3-phosphocholine) were added. The solvents were evaporated and 0.5 mL of hexane/MTBE (200:0.8, v/v) was added. Sep-Pak® Vac 1 cc (100 mg) silica cartridges (Waters, Milford, MA) were connected to a vacuum chamber and equilibrated with 1.0 mL of hexane/MTBE (96:4) and 3.0 mL of hexane. The dissolved sample was applied to the cartridge that was subsequently eluted with 4.5 mL of hexane/MTBE (200:0.8, v/v). This solvent elutes cholesteryl esters, which, however were found only in trace amounts and were therefore not analyzed. Next, the sample was eluted with 6 mL of hexane/MTBE (96:4, v/v) to obtain the triacylglycerol (TAG) fraction. A 3 mL amount of MTBE/acetic acid (100:0.2, v/v) was then used to collect a fraction that was discarded, after which phospholipids (PL) were collected with 5 mL of MTBE/methanol/water (5:8:2, v/v). The fractions were evaporated to dryness with nitrogen and dissolved in 1 mL of hexane (TAG) or chloroform (PL).

2.6. Fatty acid analysis

Fatty acid methyl esters (FAME) were prepared in 90–95 °C by boron trifluoride-catalyzed transesterification from 0.5 mL of each fraction after the solvent was evaporated under nitrogen (Morrison & Smith, 1964; Ågren, Julkunen, & Penttilä, 1992). FAMEs (dissolved in hexane) were analyzed by gas chromatography with flame ionization detection (GC-FID) (PerkinElmer AutoSystem, Norwalk, CT) using a DB-23 column (60 m × 0.25 mm i.d., 0.25 μm film thickness; Agilent Technologies, Palo Alto, CA). The FAMEs were identified with help of 68D FAME mixture (Nu-Chek-Prep, Inc.).

2.7. Vitamin D analysis

Internal standard (4 μg/mL of ergocalciferol) was added to 5 g of skinned fillet homogenates (duplicate samples). For quantification,

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the concentrations of the standard solutions were verified with a spectrophotometer (UV-2401PC, Shimadzu, Kyoto, Japan). The homogenate was mixed and lyophilized to dryness (approx. 1.5 days) by using a Modulyo 4 K Freeze Dryer (Edwards, Crawley, England). To the dried sample, 20 mL of ethanol, 10 mL of potassium hydroxide solution (25 g of potassium hydroxide dissolved in 25 mL of water), 0.5 g of ascorbic acid, and 1 mL of water was added. The sample was saponified overnight at room temperature by using magnetic stirrer (NMKL method 167, 2000; Mattila et al., 1993; Bourgeois, 1988).

A 20 mL amount of sample was applied to a column (EXtrelut® NT20, No. 11737, Merck) packed with EXtrelut® NT material (No. 11738, Merck). After the sample was adsorbed to the column material, the lipid fraction was collected with 3 × 20 mL of *n*-heptane. The eluate was evaporated to dryness and dissolved in 15 mL of *n*-heptane. Bond Elut Si-cartridges (500 mg, Varian, Palo Alto, CA) were equilibrated with 5 mL of *n*-heptane after which all of the samples was applied. The cartridge was washed with 5 mL of *n*-heptane and 10 mL of 0.5% *n*-heptane in isopropanol. Vitamin D fraction was eluted with 10 mL of 1% *n*-heptane in isopropanol. The eluate was evaporated to dryness and dissolved in 1.5 mL of *n*-heptane. The sample was purified by HPLC by using a μ-Poracil column (300 mm × 3.9 mm, 10 μm; Waters). A 1 mL amount of sample was injected onto the column and vitamin D fraction, detected at 265 nm, was collected with *n*-heptane/isopropanol/tetrahydrofuran (98:1:1, v/v) with a flow rate of 1.0 mL/min. The column temperature used was 40 °C. The vitamin D fraction was evaporated to dryness and dissolved in 150 μL of methanol/water (90:10, v/v). A 10 μL amount of sample was injected onto Vydac® C_{18} column (150 mm × 2.1 mm, 5 μm; Grace, Deerfield, IL) equipped with a Waters 486 UV detector set at 265 nm. The column was eluted with methanol/water (90:10, v/v) for 15 min. The flow rate was 0.2 mL/min and the column temperature was 40 °C.

2.8. Sensory quality

Evaluations were conducted in a sensory evaluation laboratory (ISO 8589) in University of Turku. Sample preparation and the evaluations were conducted following the basic principles of sensory evaluation. Fish were evaluated only in October 2006. Fillets with skin and scales were cut crosswise into 2 cm wide slices. Half of the slices were steam cooked for eight minutes each slice wrapped in aluminum foil. Cooked samples were evaluated after five minutes cooling in room temperature. Half of the slices were evaluated as raw.

Sensory properties of white fish of different origin were investigated with trained sensory panel ($n = 12$) by generic descriptive analysis. The sensory descriptors were created during the training sessions. Color of the flesh, freshness of aroma, hardness and springiness were evaluated of the raw slices. Hardness of the raw slices was evaluated from the thickest part of the slice. The flesh was pressed with forefinger and the power needed to press the flesh was evaluated. The more power needed the harder the flesh was. Springiness of the raw flesh was evaluated by pressing with forefinger and when released the returning of the shape and size was evaluated. The quicker the flesh returned to its original shape and size the springier the flesh was. Total aroma intensity, total flavor intensity, hardness and cohesiveness were evaluated of the cooked slices. Hardness was evaluated by biting the cooked flesh between molars and evaluating the amount of power needed for the first bite. Cohesiveness was evaluated when the sample was chewed between molars and felt how cohesive the sample is. Five fish of both origins were evaluated by each assessor in two separate sessions.

Consumer test comparing whitefish of different origin was conducted in the same laboratory. The fish evaluated were caught a year later (also October) than those evaluated by the sensory panel and analyzed chemically. Sample preparation was similar as in the evaluations with sensory panel but the samples were only evaluated as cooked. Consumer test was conducted using a 9-point hedonic scale where 9 is 'like extremely' and 1 is 'dislike extremely'. Consumers evaluated the pleasantness of the samples in aroma, flavor, texture and overall pleasantness. 52 consumers participated in the test, 14 men and 38 women. Each assessor evaluated two samples of wild and two samples of farmed white fish.

2.9. Statistical methods

SPSS 14.0 for Windows (Chicago, IL) was used for the analysis of data. Normal distribution of the chemical data was tested with the Shapiro–Wilk test. Homogeneity of variances was tested with the Levene's test, and the statistical differences between different groups were studied using the one-way analysis of variance (ANOVA) or the Brown–Forsythe test, depending on the homogeneity of variances. Tukey's honestly significant difference (HSD) test and Tamhane's T2 tests were used as post hoc tests depending on the homogeneity of variances. When the chemical data were not normally distributed, Kruskal–Wallis test and Mann–Whitney *U*-test with Bonferroni corrections was used. When only two groups were compared, either *t*-test or Mann-Whitney *U*-test was used depending on the distribution of the data.

3. Results

3.1. Fat composition

The most significant difference between the fatty acid compositions of fish caught in different seasons was that the proportion of docosahexaenoic acid (DHA; 22:6$n-3$) of the total PL fatty acids was considerably higher in fish in spring (both farmed and wild) compared with autumn (Tables 1 and 2). The seemingly higher proportion of TAG DHA in wild fish caught in spring compared with fish caught in autumn was not statistically significant. Likewise, the proportion of PL DHA in farmed fish appeared to be higher compared with wild fish, but the difference did not reach statistical significance.

Farmed fish contained 3–4 times more lipids than wild fish (Table 3). Table 3 demonstrates that there are rather large differences in TAG/PL-ratios between different groups. According to the data, the proportion of PL fatty acids of total lipids was remarkably high in wild fish caught in spring. It is noteworthy that the there was a rather large variation in the proportion of phospholipids within the groups of five fish (values not shown). It seems that especially in wild fish caught in spring, the proportion of PL DHA of the total lipids is much higher than in wild fish caught in autumn (Tables 1 and 3). However, the absolute amount of DHA (as mass percentages of the skinned fillet) was not higher in the wild spring fish, since it contained slightly less total lipids than the wild autumn fish (Table 4). Table 4 also shows that the fillets of farmed fish contained more eicosapentaenoic acid (EPA; 20:5$n-3$) and DHA (from TAG and PL) than the fillets of wild fish.

3.2. Contents of vitamin E and D

Vitamin E contents of the fillets are shown in Table 5. Farmed fish proved to be a more significant source of vitamin E than wild fish, reflecting the higher fat content. Specifically, α- and

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Table 1
Fatty acid compositions of the triacylglycerols of the skinned whitefish fillets.[A]

Group[B] Fatty acid	1	2	3	4
14:0	3.08 ± 0.42[a]	3.96 ± 0.17[b]	2.61 ± 0.72[ac]	3.91 ± 0.14[bc]
16:0	17.25 ± 0.68[a]	14.00 ± 0.75[b]	17.31 ± 1.31[ac]	13.96 ± 0.47[b]
16:1*n* − 7	14.76 ± 2.52[a]	6.69 ± 0.33[b]	10.49 ± 1.98[ac]	7.40 ± 0.63[b]
18:0	5.19 ± 0.43[a]	2.23 ± 0.28[b]	4.04 ± 0.71[ac]	2.19 ± 0.13[b]
18:1*n* − 9	20.52 ± 5.75[a]	22.99 ± 1.20[a]	24.79 ± 5.67[a]	25.41 ± 1.28[a]
18:1*n* − 7	5.88 ± 0.78[a]	3.07 ± 0.14[b]	4.82 ± 0.45[ac]	2.99 ± 0.18[b]
18:2*n* − 6	2.81 ± 1.14[a]	7.97 ± 0.38[b]	3.35 ± 0.81[ac]	8.02 ± 0.38[b]
18:3*n* − 3	2.07 ± 0.62[a]	2.63 ± 0.05[a]	1.71 ± 0.83[a]	2.37 ± 0.13[a]
20:1*n* − 9	1.77 ± 0.49[a]	6.12 ± 0.45[b]	1.90 ± 1.18[ac]	6.16 ± 0.27[b]
20:2*n* − 6	1.17 ± 0.45[a]	0.69 ± 0.15[a]	0.76 ± 0.31[a]	0.57 ± 0.06[a]
20:4*n* − 6	2.98 ± 0.72[a]	0.53 ± 0.08[b]	2.13 ± 1.57[ab]	0.46 ± 0.03[b]
20:5*n* − 3	6.76 ± 0.94[a]	5.81 ± 0.37[a]	6.90 ± 1.97[a]	5.21 ± 0.25[a]
22:1*n* − 9	0.00 ± 0.00[a]	0.80 ± 0.09[b]	0.00 ± 0.00[ac]	0.69 ± 0.04[b]
22:6*n* − 3	10.11 ± 2.72[a]	12.38 ± 0.51[a]	13.91 ± 5.36[a]	11.45 ± 0.73[a]
Others	5.67 ± 1.69[a]	10.11 ± 0.95[b]	5.28 ± 1.82[ac]	9.21 ± 0.54[b]

[A] Results expressed as weight percentages (%) of the total fatty acids of triacylglycerols (means ± SD, $n = 5$). Different letters in a row indicate significant differences between the groups ($P < 0.05$).
[B] Groups: 1, autumn, wild; 2, autumn, farmed; 3, spring, wild; 4, spring, farmed.

Table 2
Fatty acid compositions of the phospholipids of the skinned whitefish fillets.[A]

Group[B] Fatty acids	1	2	3	4
14:0	0.77 ± 0.15[a]	1.81 ± 0.28[b]	0.61 ± 0.17[a]	0.43 ± 0.62[a]
16:0	24.48 ± 2.75[ab]	25.75 ± 2.49[a]	23.12 ± 0.58[b]	25.44 ± 2.24[ab]
16:1*n* − 7	2.50 ± 0.88[a]	1.65 ± 0.59[ab]	1.29 ± 0.31[b]	0.24 ± 0.54[b]
18:0	6.24 ± 1.05[a]	5.46 ± 1.18[a]	5.13 ± 0.28[a]	5.66 ± 1.73[a]
18:1*n* − 9	5.29 ± 1.67[a]	8.00 ± 1.39[b]	5.87 ± 0.80[ab]	7.11 ± 0.81[ab]
18:1*n* − 7	2.10 ± 1.18[ab]	1.83 ± 0.26[a]	2.32 ± 0.20[b]	1.28 ± 0.87[ab]
18:2*n* − 6	1.07 ± 0.42[a]	2.95 ± 0.51[b]	0.72 ± 0.30[a]	2.12 ± 1.21[ab]
18:3*n* − 3	0.93 ± 0.43[a]	0.94 ± 0.57[ab]	0.31 ± 0.40[ab]	0.00 ± 0.00[b]
20:1*n* − 9	0.12 ± 0.08[a]	1.38 ± 0.86[a]	0.00 ± 0.00[a]	0.00 ± 0.00[a]
20:2*n* − 6	0.51 ± 0.06[a]	0.00 ± 0.00[b]	0.13 ± 0.21[ab]	0.00 ± 0.00[b]
20:4*n* − 6	5.72 ± 1.35[a]	1.78 ± 0.31[b]	3.71 ± 1.91[abc]	0.44 ± 0.63[c]
20:5*n* − 3	9.78 ± 1.79[a]	6.69 ± 0.46[a]	7.34 ± 1.43[a]	8.11 ± 0.96[a]
22:1*n* − 9	0.04 ± 0.08[a]	0.44 ± 0.45[a]	0.00 ± 0.00[a]	0.00 ± 0.00[a]
22:6*n* − 3	37.26 ± 1.53[a]	39.00 ± 1.59[ab]	47.40 ± 4.82[bc]	49.05 ± 2.13[c]
Others	3.20 ± 1.03[a]	2.31 ± 0.55[a]	2.05 ± 0.70[a]	0.12 ± 0.26[b]

[A] Results expressed as weight percentages (%) of the total fatty acids of phospholipids (means ± SD, $n = 5$). Different letters in a row indicate significant differences between the groups ($P < 0.05$).
[B] Groups: 1, autumn, wild; 2, autumn, farmed; 3, spring, wild; 4, spring, farmed.

Table 3
Amount of total lipids and proportions of triacylglycerol (TAG) and phospholipid (PL) fatty acids of the total lipids in the skinned whitefish fillets.[A]

Group[B]	1	2	3	4
Total lipids	3.4 ± 1.1[a]	9.7 ± 1.6[b]	1.9 ± 0.5[a]	9.3 ± 3.2[b]
TAG fatty acids	51.5 ± 6.8[a]	72.0 ± 3.4[b]	38.3 ± 11.6[a]	65.3 ± 4.0[b]
PL fatty acids	28.0 ± 10.9[ab]	19.6 ± 3.7[ac]	40.5 ± 11.1[b]	10.7 ± 4.9[c]

[A] Results expressed as weight percentages (%) (means ± SD, $n = 5$). Different letters in a row indicate significant differences between the groups ($P < 0.05$).
[B] Groups: 1, autumn, wild; 2, autumn, farmed; 3, spring, wild; 4, spring, farmed.

γ-tocopherol contents were higher in farmed fish, the amounts still being rather low. In wild fish, total tocotrienol content of the samples was higher in autumn compared with spring. In farmed fish, both tocopherol and tocotrienol contents seemed to be higher in autumn, although statistical significance was not reached.

Contents of vitamin D were rather high both in farmed and wild fish (Table 6). The content was slightly higher in farmed compared with wild fish, but the difference between the groups was not statistically significant. Vitamin D was only determined in fish caught in autumn.

Table 4
Proportions of triacylglycerol- and phospholipid-derived eicosapentaenoic acid (20:5*n* − 3) and docosahexaenoic acid (22:6*n* − 3) in the skinned whitefish fillets.[A]

Group[B]	1	2	3	4
20:5*n* − 3	0.20 ± 0.05[a]	0.53 ± 0.06[b]	0.11 ± 0.04[a]	0.39 ± 0.12[b]
22:6*n* − 3	0.53 ± 0.22[ab]	1.58 ± 0.14[c]	0.45 ± 0.10[bd]	1.13 ± 0.22[e]

[A] Results expressed as weight percentages (%) (means ± SD, $n = 5$). Different letters in a row indicate significant differences between the groups ($P < 0.05$).
[B] Groups: 1, autumn, wild; 2, autumn, farmed; 3, spring, wild; 4, spring, farmed.

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Table 5
Amount of tocopherols and tocotrienols in the skinned whitefish fillets.[A]

Group[B]	1	2	3	4
α-Tocopherol	0.07 ± 0.16[a]	0.73 ± 0.27[b]	0.05 ± 0.06[a]	0.43 ± 0.47[ab]
β-Tocopherol	0.00 ± 0.00[a]	0.00 ± 0.00[a]	0.00 ± 0.00[a]	0.00 ± 0.00[a]
γ-Tocopherol	0.00 ± 0.00[a]	0.10 ± 0.03[b]	0.00 ± 0.00[a]	0.07 ± 0.03[b]
δ-Tocopherol	0.00 ± 0.00[a]	0.00 ± 0.00[a]	0.01 ± 0.00[a]	0.00 ± 0.01[a]
Total tocopherols	0.07 ± 0.16[a]	0.83 ± 0.28[b]	0.06 ± 0.06[a]	0.51 ± 0.50[ab]
Total tocotrienols	0.03 ± 0.01[a]	0.02 ± 0.01[ab]	0.01 ± 0.00[b]	0.00 ± 0.01[b]

[A] Results expressed as mg/100 g (means ± SD, $n = 5$). Different letters in a row indicate significant differences between the groups ($P < 0.05$).
[B] Groups: 1, autumn, wild; 2, autumn, farmed; 3, spring, wild; 4, spring, farmed.

Table 6
Amount of vitamin D in the skinned whitefish fillets.[A]

Group[B]	1	2
Vitamin D (μg/100 g)	19.2 ± 4.9	24.1 ± 2.2

[A] Results expressed as means ± SD, $n = 5$.
[B] Groups: 1, autumn, wild; 2, autumn, farmed.

3.3. Sensory quality

Results of the sensory panel evaluations were examined as averages of fish of different origin, farmed or wild. Figs. 1 and 2 show the differences between fish of different origin. Aroma of raw farmed whitefish was less algae like than wild one ($p < 0.05$). Raw farmed whitefish was harder ($p < 0.001$), less springy ($p < 0.05$) and lighter in flesh color ($p < 0.001$) than wild whitefish. Cooked, farmed whitefish had slightly stronger flavor than wild one ($p < 0.05$). There were no other statistically significant differences between the sensory descriptors of cooked fish samples.

There was no significant ($p < 0.05$) difference in pleasantness between whitefish of different origin in any of the evaluated characteristics (Fig. 3).

4. Discussion

In recent years, evidence demonstrating the health benefits of $n-3$ polyunsaturated fatty acids (PUFAs) in fish together with diminishing supplies of wild fish have given birth to a dramatic expansion in aquaculture. However, only a little has been published about the effects of rapid changes in the fish industry on PUFA or saturated fatty acid (SFA) levels in emerging farmed species of fish (Weaver et al., 2008). The health benefits of the $n-3$ PUFAs in fish have been well documented (Mozaffarian et al., 2004). A meta-analysis examining fish consumption and coronary heart disease (CHD) in 13 cohort studies revealed an inverse relationship between fish consumption and CHD as well as sudden cardiac death, where each 20 g/day increase in fish consumption was associated with a 7% lower risk of fatal CHD (He et al., 2004). In the present study, both wild and farmed whitefish proved to be good sources of the very-long chain $n-3$ PUFAs EPA and DHA. Also, the relative proportions of these fatty acids of the total fatty acids

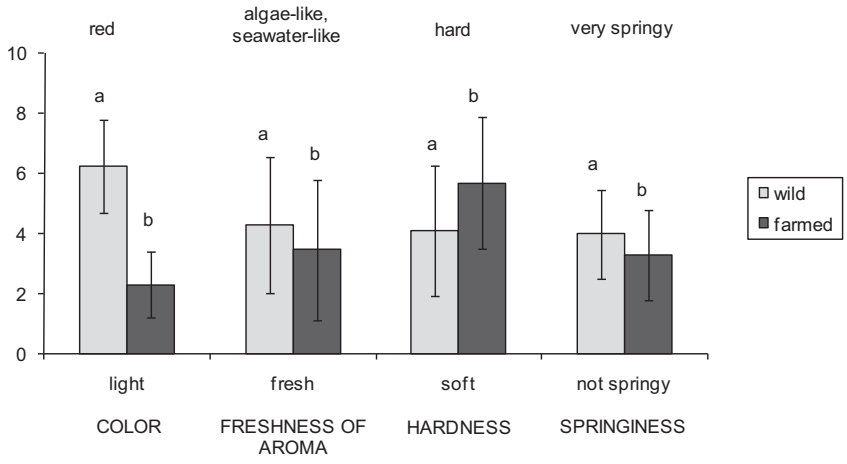

Fig. 1. Sensory evaluation of fresh whitefish evaluated raw (12 panelists, five replicates/origin; total of finished evaluations: $n = 58$, wild; $n = 57$, farmed).

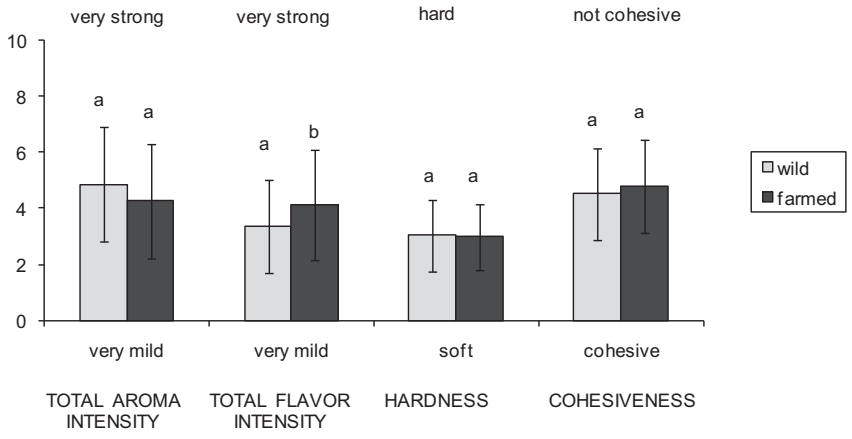

Fig. 2. Sensory evaluation of fresh whitefish evaluated cooked (12 panelists, five replicates/origin; total of finished evaluations: $n = 58$, wild; $n = 57$, farmed).

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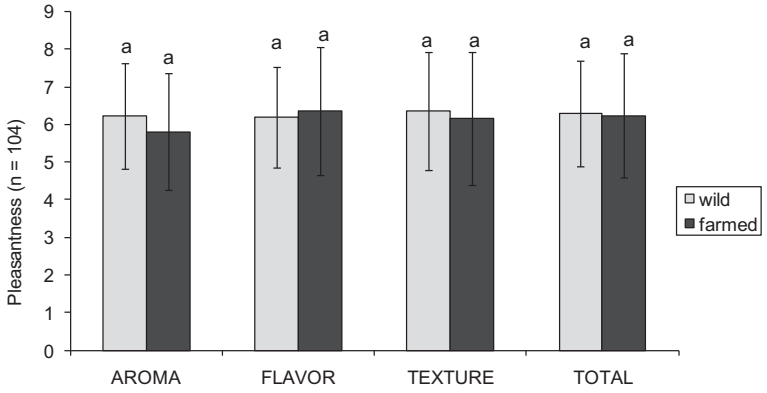

Fig. 3. Results of the consumer test. Pleasantness of wild and farmed whitefish (52 panelists, two replicates/origin; total of finished evaluations, $n = 104$).

of TAG and PL were comparable in both wild and farmed fish fillets. There was a considerably higher PL DHA proportion in spring fish (both wild and farmed) compared with autumn fish, which may have to do with cold adaptation during wintertime. During winter season, when the amount of storage fat decreases, adequate level of DHA needs to be maintained in order to maintain membrane fluidity and hence functional metabolism. Relative proportion of linoleic acid (18:2$n-6$) of total fatty acids of both TAG and PL was higher in farmed fish compared with wild fish, but this was compensated by slightly higher proportion of arachidonic acid (20:4$n-6$) in TAG and PL of wild fish.

Vitamin E contents (Table 5) of the fish fillets were quite insignificant from human nutrition point of view, since recommended daily intake of vitamin E (as α-tocopherol equivalents) for men is 10 mg (Finnish national nutrition council: Finnish nutrition recommendations, 2014). At its best, less than 10% of the recommended daily intake could be obtained by eating a portion of 100 grams of the whitefish fillets studied. However, European whitefish proved to be a significant source of vitamin D (Table 6). The results suggest that 100 g of whitefish provides twice the minimum daily need of vitamin D (Finnish national nutrition council: Finnish nutrition recommendations, 2014).

As reported by Farmer et al. (2000), differences in texture may be caused by a range of factors including swimming activity, diet and pre- and post-slaughter handling. These are inherently different between the origins. Higher lipid content of farmed whitefish may have a role in differences between sensory properties. In their study, Olsson et al. (2003) reported a strong correlation between fat content and firmness of cooked Atlantic halibut. However, the results were not in accordance with all earlier studies. In our study, we measured hardness, which is a comparable attribute to firmness, and found no significant difference between cooked whitefish of different origin, although there was a considerable difference in fat content. Fat content may, however, have affected the differences in the texture of the raw samples, as raw, farmed fish was evaluated harder than wild. Light color is a desired characteristic of whitefish and farmed fish seems to have an advantage over wild fish. This is most probably due to the more easily controlled early processing, and thereby bleeding, of farmed fish.

Individual differences between fish samples may affect the results of sensory analyses. In our study, generic descriptive analyses were divided into two days, and there may be minor differences in the properties of the samples analyzed in different days due to aging. The consumer test was made one year after other sensory analyses from fresh fish samples. Thus, conclusions made based on the consumer test may not be directly comparable with the conclusions made based on other types of analyses and measurements.

In Finland, increased aquaculture has made the overall supply of European whitefish more stable. As the results suggest, its good lipid quality and sensory attributes combined with good availability are valuable both from nutritional and marketing point of view.

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