Sveriges lantbruksuniversitet
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Fakulteten för naturresurser och jord-bruksvetenskap
Institutionen för livsmedelsvetenskap

An investigation of the lipid content and lipid composition in Atlantic salmon, pink salmon and striped catfish, obtained at the local retailer in Uppsala, Sweden

En undersökning av lipidhalt och lipidsammansättning i Atlantlax, pinklax och pangasiusmal, från lokala livsmedelsbutiker i Uppsala

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ABSTRACT

The aim of this study is to investigate the lipid content and lipid composition of fatty acids in Atlantic salmon (*Salmo salar*), pink salmon (*Oncorhynchus gorbuscha*) and striped catfish (*Pangasius hypophthalmus*), obtained at the local retailers in Uppsala, Sweden. Then explore the cause of the differences in the fatty acids between the three fish species. In addition, the present data will be compared to the data available at National Food Administration in Sweden (SLV) and National Institute of Nutrition and Seafood Research in Norway (NIFES).

Fish is a main food that provides n-3 long chain polyunsaturated fatty acids (LCPUFA), and is to many people known to be a healthy choice as food. It is particularly the n-3 LCPUFAs that have been shown to have positive effects on for example cardiovascular disease and cancer. Docosahexaenoic (DHA) and eicosapentaenoic (EPA) are n-3 LCPUFAs, present in fish and fish oils. The demand for fish raw material as fish feed is rising around the world, and this depends on a steady increase of aquaculture production. A change from using fish raw material to use more ingredients based on vegetables have been investigated. There is a consequence of this change from fish raw material to plant based material on human health, where the degree of long chain n-3 fatty acids have been lowered in the fish and the beneficial health effects of fish on humans is therefore decreasing. In vegetable oils there is a high concentration of n-6 and n-9 fatty acids that is mostly linoleic acid and oleic acid respectively. In vegetable oils there are also low or moderate levels of n-3 fatty acids (excluding linseed oil) of mostly α-linolenic acid. Although vegetable oils do not have the long chain highly unsaturated fatty acids (LCHUFA), EPA and DHA.

In this study seven different samples were taken from Atlantic salmon, pink salmon and striped catfish. The samples all have different origin and label, and all the samples were from a farmed fish fillet except one wild fish. The samples tested in this study were all homogenized and the fat of the samples was extracted. Fatty acid composition was analyzed by a gas chromatograph (GC).

The fat content in the four farmed Atlantic salmon samples was: 7.0, 7.6, 9.4 and 7.4 % respectively. The fat content in the wild pink salmon was: 3.0 %. The fat content in the two farmed striped catfish samples was 0.3 and 0.5 %. The proportion of fatty acids was all measured in % of total fatty acids. The percentage of EPA (20:5 n-3) and DHA (22:6 n-3) was higher in the farmed Atlantic salmon and wild pink salmon, compared to the farmed striped catfish, as expected. Linoleic acid (18:2 n-6) was significantly higher in the farmed striped catfish, and lower in both the farmed Atlantic salmon and wild pink salmon. α-linolenic acid (18:3 n-3) was present at a smaller percentage in the farmed striped catfish than in both the farmed Atlantic salmon and wild pink salmon. The n3/n6 ratio was significantly higher in the wild pink salmon, than in both the farmed Atlantic salmon and farmed striped catfish.

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1 INTRODUCTION

1.1 In general about fish

Fish and other aquatic organisms, especially the ones living in the oceans, are different from plants and other animals. Fish and other aquatic organisms have a high content of long chain polyunsaturated fatty acids (LCPUFA) (Högberg & Pickova 2002).

Fish is well known to be a healthy choice as food, and the human consumption of fish is increasing around the world. It is particularly the n-3 long chain PUFA that is desirable to have in the human diet. The fish muscle is around 60 % of the fish body mass, and the fish muscle is the primarily part of the fish that is consumed by humans. The fatty acid composition varies in different fish tissues (Pan 2013).

Around 75 percent of all the fish that is captured is eaten by humans, the other 25 percent is used for fish oil or fish meal and then primarily given to animals as animal feed. During the last years the fish that is sold as frozen fish and fish that is sold as fresh have had an increase in volume. Cephalopods, crustaceans and molluscs have had an increase, while finfish has gone down. In developed countries the human fish consumption is usually higher than it is in developing countries (an important exception is the minor developing island states where the fish consumption is higher). The Near East and Africa have the lowest consumption of fish (www, fao.org 1, 2013).

The aim of this study is to investigate the lipid content and lipid composition of fatty acids in Atlantic salmon (*Salmo salar*), pink salmon (*Oncorhynchus gorbuscha*) and striped catfish (*Pangasius hypophthalmus*), obtained at the local retailers in Uppsala, Sweden. Then explore the cause of the differences in the fatty acids between the three fish species. In addition, the present data will be compared to the data available at National Food Administration in Sweden (SLV) and National Institute of Nutrition and Seafood Research in Norway (NIFES).

1.2 Fish fatty acids

Fatty acids are organic compounds that mainly consist of carbon, hydrogen and oxygen. The fatty acids are divided into saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) depending on how many double bonds they have. PUFA have more than one double bond (actually between two and six double bonds (Ekström 2003)), MUFA have one double bond and SFA have none double bond (Högberg & Pickova 2002). According to Pickova and Högberg (2002) fatty acids have the following functions in animals and plants:

- have a structural significance for the cell membranes
- are used as energy
- provide an energy reservoir

Some of the PUFA that are present in the food are essential to humans, like α-linolenic acid (also called ALA, 18:3 n-3) and linoleic acid (18:2 n-6). Essential means that the fatty acid has to be provided to humans through the food source (Ekström 2003). The majority of the mammals and humans have enzyme systems which can transform α-linolenic acid and linoleic acid by prolonging the carbon chain and by adding more double bonds. So α-linolenic acid can for example form eicosapentaenoic acid (also called EPA, 20:5 n-3) (www, ne.se 1, 2013). Despite some biosynthesis production of n-3 PUFA in mammals (which includes humans) and marine fish, the main part of the PUFA comes from the diet these individuals eat (Sijtsma & Swaaf 2004).

A food that have EPA in it, also have the derivatives docosahexaenoic acid (DHA, 22:6 n-3) and docosapentaenoic acid (DPA, 22:5 n-3) but in different proportions (Rust & Whelan 2006). DPA is an unusual fatty acid, but it is present in animal lipids in small levels (Ratledge 2004). EPA and DHA are highly present in fish and fish oils (fish and fish oil are the highest origins of EPA and DHA). Among the two fatty acids EPA and DHA, DHA is present in highest amounts in fish, and the levels of DHA in fish is two to five times higher than EPA (Rust & Whelan 2006). In nearly all of the fishes, linoleic acid and α-linolenic acid (C18 PUFA) can be desaturated and elongated to be long chain PUFA in the form of arachidonic acid (20:4 n-6), DHA, EPA or DPA in a low percentage. Because of this low percentage it is preferable to increase the n-3 long chain PUFA in the body composition of the fish (Pan 2013). Therefor the fishes need to have n-3 long chain PUFA in their feed.

1.3 Atlantic salmon

Atlantic salmon has the Latin name *Salmo salar*, and is a salmonid fish (Nielsen, Stradmeyer & Verspoor 2007). Atlantic salmon can measure up to 150 cm in length but is usually 40-130 cm (www, fao.org 2, 2013), and weigh up to 47 kg (www, fishbase.org 1, 2014). The Atlantic salmon is a carnivorous fish (Eide et al 2009), which means that this fish eats other animals (www, ne.se 2, 2013). Atlantic salmon has developed during the last ten years to be a "super-commodity" (a commodity that is sold in large numbers). The aquaculture of Atlantic salmon has reached a number of around 1.5 million tons in 2009, where Norway was the largest aquaculture producer followed by the United Kingdom, Chile, and Canada (Asche et al 2011). According to FAO (Food and Agricultural Organization of the United Nations) the total global aquaculture production of Atlantic salmon in 2011 was 1721254 tons (www, fao.org 2, 2013).

The Atlantic salmon is either anadromous or non-anadromous, which depends on differences in life-history. In the most rivers Atlantic salmon are anadromous and do swim (migrate) to the sea. But in some other rivers a migration return is impossible because of impassable waterfalls (this type of Atlantic salmon is called "landlocked" forms). However, other populations have their whole life in fresh water, despite the fact that there are no barriers to the fish's migration to the sea. The populations that have the anadromous forms are most common and familiar, and this form is the archetypal Atlantic salmon. When Atlantic salmon is living in the sea, it feeds on fish prey and crustacean (Nielsen, Stradmeyer & Verspoor 2007).

The wild anadromous Atlantic salmon is present in the:

> "Atlantic coasts of Europe, from Barents Sea, northern Norway and Baltic southward to northern Portugal, also around Iceland and southern Greenland; not in Mediterranean. Elsewhere, coasts of Canada and North America" (www, fao.org 2, 2013).

1.4 Pink salmon

Pink salmon has the Latin name *Oncorhynchus gorbuscha*. Pink salmon is an anadromous Pacific fish, and has a weight of around 5 kg and a size of up to 75 cm (normally about 40-56 cm as spawning adults). The wild pink salmon is caught with trawl nets and gillnets. In 2011 the fish had a total catch of 585315 tons in the world. Pink salmon is a Pacific fish who was first introduced to rivers affluent to White sea (ouside northwest of Russia) and Barents Sea, but is now more spread over the world (www, fao.org 3, 2013). Pink salmon is a food fish which belong to the family Salmonidae (Britannica concise encyclopedia 2006).

The pacific salmon (like pink salmon) is an anadromous fish, and this fish do have a migration from the ocean to streams and rivers for spawning. When the eggs has been hatched, the juveniles (not matured) spends some time that differ from weeks to years in freshwaters (this depends on which species and which stock). After some time in freshwater the pacific salmon disperse into ocean environment where they can mature and eat before they can go back to the streams and rivers for spawning and later on die (www, fao.org 4, 2013).

1.5 Striped catfish

The striped catfish belongs to the group Pangasiidae and has a wide array of common names in English that is striped catfish, iridescent shark-catfish and Sutchi catfish. The Latin name is *Pangasius hypophthalmus*, and the fish can have a total length of 130 cm and a weight of up to 44 kg. The largest producer of striped catfish in the world is Vietnam. Other important producers are Bangladesh, China, Cambodia, Myanmar, Lao People´s Democratic Republic and Thailand. According to some numbers from FAO the total aquaculture production of striped catfish in the world was 177386 tons in the year 2011 (www, fao.org 5, 2013).

Iridescent shark (another word for striped catfish) is present in rivers in South East Asia, mainly in Vietnam, Laos and Thailand (Aliyu-paiko et al 2011). Striped catfish is an omnivorous (which means that this fish eats everything, both vegetable based and animal based food (www, ne.se 3, 2013)) (Caproni et al 2008). Just like all other pangasiid species, striped catfish is a fish that makes migrations over many hundred kilometers (potamodromous), between upstream sanctuary spawning habitats, nursery habitats and downstream feeding. Striped catfish as has been mentioned earlier are omnivorous, who in the wild feeds on higher plants, algae, insects and zooplankton, while larger individuals also may feed on fish, fruit and crustaceans (www, fao.org 5, 2013).

1.6 Human nutrition

The conversion of α-linolenic acid to EPA and later on DHA is limited respectively low in humans and that's why EPA and DHA should be ingested through the diet (Mráz 2012).

There are some physiological beneficial effects especially from of EPA and DHA, which are:

- effect on cancer, diabetes and hypertension
- cardioprotective
- essentiality in membrane structure and related functions

- effect on autoimmune diseases and neuropsychiatric disorders (Hosakawa, Miyashita & Narayan 2006)

The health beneficial effects of n-3 highly unsaturated fatty acids (for example EPA, DHA and α-linolenic acid) are known, and this type of fatty acids is associated with a lower risk of cardiovascular disease and some cancer forms. α-linolenic acid is present in vegetable oils, which for example are soybeen oil, rapeseed oil (also called canola oil) and linseed oil (Nagao & Yanagita 2008, Mráz 2012). Trattner (2009) named some additional health effects of n-3 fatty acids in a study (e.g. reduced heart rate, depression and inflammatory diseases). n-6 fatty acids have an opposite function compared to n-3 fatty acids have, where n-6 PUFA are of great importance in inflammation and immune response, whereas n-3 PUFA are anti-inflammatory (Pan 2013).

A typical example is the Eskimos in Greenland where the outbreaks of heart disease are low, and this correlating with a high intake of long chain n-3 PUFA. In a research done during a period from 1979 to 1983 the amounts of deaths caused by heart disease in Greenland was half of what has been reported in Denmark. Within the Japanese population the consumption of seafood was higher in fishing villages in a comparison with farming villages. Correlating with lower outbreaks of coronary artery disease in the fishing villages (Hamazaki & Okuyama 2001).

Our ancestors did actually eat a diet with the same amounts of n-6 fatty acids and n-3 fatty acids, while we in the modern society after a great advancement of agriculture has changed our diet to a ratio of n-6 to n-3 fatty acids to over 7:1. This is due to the fact that the today´s agriculture has increased the accessibility of refined fats, with particularly an increase in vegetable oils (Damodaran, Fennema, & Parkin 2007).

1.7 Aquaculture and fish feed

Because aquaculture production is increasing steadily in the world, it will meet some great challenges when the demand for fish raw material as fish feed is rising. This increased demand for fish feed has led to investigation on changing from fish raw material to ingredients that are based on plants. By replacing fish raw material with plant based material the level of the long chain n-3 fatty acids will lower the beneficial effects of the fish on human health (Trattner 2009).

Factors like season, genetics, water temperature, diet (fish feed) and fish maturity all have an impact on the nutrient content of seafood and thereby the seafood for consumption. All these factors have an effect on the health benefits for humans. These factors can be manipulated to some degree in aquaculture, while in the wild these factors can give variation in the nutritional value. Processing that is done with sea food post-harvest will also affect the nutrient content (like for example minced fish meat) (Lund 2013). The lipids in the fish feed has a substantial influence on the fatty acid composition in the fish according to Henderson and Tocher (1987).

In vegetable oils there is a high concentration of n-6 and n-9 fatty acids, mostly linoleic acid and oleic acid respectively. In vegetable oils there are also low or moderate levels of n-3 fatty acids (excluding linseed oil) of mostly α-linolenic acid (Pettersson 2010). Linseed oil mainly consists of linoleic acid, oleic acid, esters of glycerol and linolenic acid (www, ne.se 4, 2013). Vegetable oils do not have the long chain highly unsaturated fatty acids (LCHUFA), EPA and DHA (Pettersson 2010).

Farmed salmon, as it is a carnivorous fish, needs a diet that has been taken from marine fish sources. During the last ten years a mixture of fish oil, animal oil and vegetable oil has been used as fish feed, and the reason is mainly the lower cost but also to reduce the use of marine fish sources. Studies on the use of replacement oils show that the fatty acid composition of the salmon is related to the diet. It has been seen that 75 % of fish oil can be changed to vegetable oil in Atlantic salmon, with no negative effect on growth, performance and fish health, but only if the n-3 long chain PUFA that is essential for the Atlantic salmon are provided (Carter, Miller & Nichols 2008).

1.7.1 Atlantic salmon

The aquaculture of Atlantic salmon first started in Norway during the late 1960s. Later on during the 1980s and 1990s the aquaculture of Atlantic salmon was primarily spread to the northwestern Europe and to Chile. The Atlantic salmon´s growth rate in aquaculture after hand increased, because of improved feeding, diets, management and genetic selection. The work to develop new fish feed for Atlantic salmon began in 1972. One finding was that a higher dietary lipid level of 18 %, instead of the former 8-10 %, raised survival and growth rate (Lim & Webster 2002).

When the new extrusion technology came in the 1990s the pelletizing of feeds permitted a higher inclusion of fat which gave a higher energy. Because of this a fast increase was seen in the lipid level in the feeds for salmon to around 30 %. Today in Norway, salmon is fed solely extruded diets, which are vacuum coated with rapeseed or fish oil (Asche et al 2011).

In salmon aquaculture feed for the fishes represent 50 % (2010) of the total operating cost. Therefore naturally these salmon farmers´ wants to use feed with lower cost per salmon produced. There have been a lot of discussions about the environmental influence of feeding salmon with marine resources. A higher use of land based plant feed and animal feed as ingredient in fish feeds is demanded today (Asche et al 2011).

1.7.2 Pink salmon

This study investigates wild Pink salmon which in this case is neither farmed in aquaculture nor given fish feed, but captured from the wild.

The commercial harvest of pacific salmon is mostly done when the adult salmon returns to spawn, mostly not directly from the rivers or streams, but in the marine areas where a lot of stocks and species are mixed. This type of harvesting is done in the marine areas because many salmon species deteriorate in their quality when they come up to their spawning habitats in the streams (therefore give a higher price when captured in the marine areas). Another reason for the fishery to have their fishing in the offshore marine areas is to avoid local overfishing. Commercial fisheries harvest five species of pacific salmon, and one is pink salmon (the others are sockeye-, chinook-, chum- and coho salmon) (www, fao.org 4, 2013).

1.7.3 Striped catfish

Recently the ongoing enlargement of the aquaculture of the *Pangasius hypophthalmus* has locally been hindered with a low production, and the explanation is the lack of quality fish feeds. Vegetables, trash fish and especially chicken viscera are the mainly fish feeds used by fish farmers. Dietary protein is a main component that affects growth of the fish, and dietary protein is also a substantial energy source. The cost for dietary proteins is far more than for carbohydrates and lipids (Aliyu-Paiko et al 2009). A replacement of trash fish will come in the near future, when trash fish is both expensive and is present at low amounts in Vietnam (Da 2012).

The aquaculture of striped catfish has the quickest growth that has been registered in any aquaculture that is based on single species. Another important approach is that over 90 % of the farmed striped catfish is exported to over 100 countries around the world. The Vietnamese striped catfish has become a “white fish” substitute in the Western countries, to replace for example cod (Bui et al 2009).

In a study from the year 2011, of *Pangasius hypophthalmus* (Sauvage, 1878) juvenile, it was stated that fish fed with feed that was based on vegetable oil diets had a performance that was better than the fish that was fed with fish oil. Another result of the study was that fish that were fed on fish oil had a slower growth rate than those fishes who fed on vegetable oils, particularly crude palm oil and soybean oil (but no negative effect on nutrient value was shown) (Aliyu-paiko et al 2011).

1.8 Fatty acid composition in salmon and striped catfish

Fatty fish, like salmon, is a primary source of the long chain n-3 fatty acids EPA and DHA. In the wild salmon, the total fat and the amount of EPA and DHA varies, and is affected by diet, season, location, water temperature, age and sex. The farmed salmon on the other hand lives in a restricted environment, but the amount of EPA and DHA in the fish feed is varying (Fleming, Harris & Kris-Etherton 2011).

Fish is the primary source of n-3 PUFAs for humans, but there is great differences in the fatty acid composition of each individual fish within the same species (Ozogul & Ozogul 2007).

Salmon which is fed a diet with a high content of n-3 fatty acids have as a result considerable high proportion of n-3 fatty acids in the flesh. When a farmed salmon is given a fish feed with fish oil as the primary fat origin, even when it is a small percentage of vegetable oil present in the fish feed, the vegetable oil will result in a substantial lowering of the n-3/n-6 ratio. The composition of PUFA and the fat content in salmon are all very important parameters that have an effect on texture, taste and color of the salmon fillet, but are also affected by factors like ranching condition, diet, season, temperature and biological differences (sex, size, age and maturity) (Jonsson, Kristbergsson & Palmadottir 1997).

In a study that investigated the nutritional quality of *Pangasius hypophthalmus* from Vietnam, the fatty acid profile of total lipids was extracted from sutchi catfish (other words for *Pangasius hypophthalmus*). The fatty acid profile of total lipids were mainly SFA (approximately 41.1-47.8 % of total fatty acids), and mostly represented by stearic acid (18:0) and palmitic acid (16:0). The monounsaturated fatty acids (approximately 33-37 % of total fatty acids), was mainly oleic acid (18:1 n-9). The PUFA was present in the sutchi catfish fillet at a low proportion (approximately 12.5-18.8 % of total fatty acids). This result with the low content of PUFA does not speak for the general assumption that fish is a good source of PUFA for humans. The fillets had a high proportion of n-6 PUFAs and a low n-3/n-6 ratio, two characteristics that are well known in many freshwater fishes (Caproni et al 2008).

The fatty acid composition in farmed salmon from Norway, pink salmon and striped catfish (Table 1) are from the Swedish National Food Administration (SLV) (www, slv.se 1, 2014).

Table 1. *Fatty acid composition in farmed salmon from Norway, pink salmon and striped catfish (g/100 g fish).*

Fatty acid	**Farmed salmon from Norway**	**Pink salmon**	***Striped catfish***
4:0 - 10:0	0.0	0.0	0.0
12:0	0.0	0.0	0.0
14:0	0.7	0.0	0.0
16:0	1.8	0.2	0.2
18:0	0.4	0.0	0.1
20:0	0.0	0.0	0,0
16:1	1.0	0.1	0.0
18:1	2.4	0.1	0.3
18:2	0.4	0.0	0.1
20:4	0.3	0.0	0.0
18:3	0.2	0.0	0.0
20:5 (EPA)	1.2	0.1	0.0
22:5 (DPA)	0.5	0.0	0,0
22:6 (DHA)	1.6	0.3	0.0
Total SFA	**3.0**	**0.2**	**0.3**
Total MUFA	**5.8**	**0.6**	**0.3**
Total PUFA	**4.8**	**0.5**	**0.1**

In the table from the Swedish National Food Administration (SLV) it is clearly seen that the striped catfish has a lower content of the fatty acids EPA, DPA and DHA. In fact the amount of EPA, DPA and DHA is so low that it can´t be calculated in the table. The farmed salmon from Norway has the highest amount of EPA, DPA and DHA, within these three fish species. Pink salmon in this table is caught in the wild, while striped catfish is farmed.

The fatty acid composition in farmed Atlantic salmon from the years 2010-2008 and 2006-2005 from nifes.no (is shown in Table 2) (www, nifes.no 1, 2014). Pink salmon and striped catfish could not be found on nifes.no.

Table 2. *Fatty acid composition in farmed Atlantic salmon mg/100g fish and total fat in g/100g , with data taken from nifes.no.*

Fatty acid	**Farmed Atlantic salmon (2010)**	**Farmed Atlantic salmon (2009)**	**Farmed Atlantic salmon (2008)**
10:0	< 1		
12:0			
14:0	619	488	517
16:0	1810	1491	1508
18:0	417	358	348
20:0		27	24
22:0	15	7	7
16:1 n-7	684	511	533
16:1 n-9	31	26	26
18:1 n-7	474	415	405
18:1 n-9	4548	4303	3917
18:1 n-11	94	70	85
20:1 n-7	29	23	28
20:1 n-9	833	668	761
20:1 n-11	93	77	94
22:1 n-9	99	88	105
22:1 n-11	818	591	732
18:2 n-6	1556	1496	1308
18:3 n-3	588	589	517
18:3 n-6			
20:4 n-3	218	168	174
20:4 n-6	62	40	61
20:5 n-3 (EPA)	809	684	731
22:5 n-3 (DPA)	405	335	365
22:6 n-3 (DHA)	1300	1026	1056
Total MUFA	**7742**	**6889**	**6813**
Total PUFA	**5652**	**4807**	**4660**
Total SFA	**2984**	**2428**	**2465**
Total fat	**15.6**	**15.7**	

Table 2 cont. *Fatty acid composition in farmed Atlantic salmon mg/100g fish and total fat in g/100g, with data taken from nifes.no.*

Fatty acid	**Farmed Atlantic salmon (2006)**	**Farmed Atlantic salmon (2005)**
10:0		
12:0		
14:0	472	611
16:0	1574	1905
18:0	361	435
20:0	25	28
22:0		
16:1 n-7	511	732
16:1 n-9	25	44
18:1 n-7	343	470
18:1 n-9	2916	3459
18:1 n-11	61	56
20:1 n-7	25	38
20:1 n-9	505	693
20:1 n-11	59	82
22:1 n-9	73	100
22:1 n-11	535	637
18:2 n-6	1049	1147
18:3 n-3	338	417
18:3 n-6		
20:4 n-3	173	208
20:4 n-6	65	120
20:5 n-3 (EPA)	763	1112
22:5 n-3 (DPA)	342	490
22:6 n-3 (DHA)	1299	1630
Total MUFA	**5178**	**6390**
Total PUFA	**4465**	**5623**
Total SFA	**2514**	**3073**
Total fat	**13.2**	**16.4**

In the tables from nifes.no has the amount of EPA, DPA and DHA a decrease from the year 2005 to the year 2010. This shows that the fish feed for the farmed Atlantic salmon in recent years have a higher inclusion of vegetable based oils (which has a lower content of EPA, DPA and DHA).

2 MATERIALS AND METHODS

2.1 Sample preparation

Seven different samples were taken from the three fishes Atlantic salmon, pink salmon and striped catfish. The samples differ in label and origin, and all the samples were from a farmed fish fillet accept one sample which was from a whole wild fish (but without the intestines and head). Another difference is if the fish was fresh or frozen in the food store. All samples were analyzed in duplicate, fourteen samples as a whole.

Table 3. Atlantic salmon (Salmon 1-4), pink salmon (Salmon 5) and striped catfish samples with sample name, different brand, different farming places and with different kind of treatment.

Sample name, brand (farmed)	Frozen	Fresh
Salmon 1, ICA (Norway)		1
Salmon 2, COOP (Norway)		1
Salmon 3, ICA (the Faroe Islands)	1	
Salmon 4, Findus (Norway)	1	
Salmon 5, LOBSTER from COOP (wild from the pacific ocean, Canada)	1	
Striped catfish 6, ICA (Vietnam)	1	
Striped catfish 7, My fish premium from WILLYS (Vietnam)	1	

2.2 Lipid analysis

2.2.1 Fat extraction

Approximately 1 g of each sample was used in duplicates. Then 10 ml of HIP (hexane : isopropanol 3:2) was added and the samples were homogenized for 3x30 seconds. 5 ml HIP was used to rinse the homogenizer between the samples. After that 6.5 ml Na_2SO_4 (6.67 %) was added, and the solution with sample was transferred by pouring it into a centrifuge bottle. The samples were shaken vigorously and centrifuged at 4000 rpm at 18°C for five minutes. The upper phase was transferred to a pre-weighed evaporation bottle. Then 1 ml of hexane was added to the centrifuge bottles, and the centrifugation bottles were shaken and centrifuged again with the same speed, temperature and time. After that the upper phase was transferred a second time to the pre-weighed evaporation bottles. Thereafter evaporation with N_2 flushing was done until the hexane was evaporated. The evaporation bottle was re-weighed, and 0.5 ml hexane was added, then rinsed and transferred with a pasteur pipet to a small glass tube. Another 0.5 ml hexane was added to the evaporation bottle, rinsed and transferred to the small glass tube. Teflon tape was used, then the samples were vortexed and stored in a freezer at -18°C.

2.2.2 Methylation

The samples was taken out from the freezer, and then placed in a fume hood. The samples were transferred from the small glass tube into small (5 ml) test tubes, and rinsed with hexane. Then the samples were evaporated with N_2 flushing until they were dry. After that 0.5 ml hexane was added. Thereafter dry methanol (with 1 tablet NaOH), BF_3 and 20 % NaCl was prepared. Then 2 ml dry methanol was added, and glass stoppers were put on. After that the samples were vortexed and incubated in a heating block at 60°C for 10 minutes. Then the samples were moved to a fume hood and 3 ml BF_3 was added, after that a glass stopper were put on and the samples was incubated in a heating block at 60°C for 10 minutes. Thereafter the samples were cooled under pouring cold water, then 2 ml 20 % NaCl and 2 ml hexane was added. Then the samples were vortexed and then leaved in a refrigerator at +8°C for 20-30 minutes. After that the upper phase was transferred into small (5 ml) test tubes and 1 ml hexane was added to the tubes which still contain the lower phases. Then the samples were vortexed and then left (the tubes which still contain the lower phases) in a refrigerator at +8°C for 20-30 minutes. Thereafter the small (5 ml) test tubes were evaporated with N_2 flushing until they were dry. Then 0.250 ml hexane was added to the dry samples. After that teflon tape was put on, the samples were vortexed and stored in a freezer at -18°C.

2.2.3 Analytical thin layer chromatography (TLC)

The methylation was checked on a TLC silica plate. A solvent was made of hexane:diethyl ether:acetic acid (85:15:1, v:v:v) one hour before using. Then the silica plate was prepared, by drawing a line with a lead pencil and mark out 7 dots plus a standard dot to show were to put the samples. Thereafter the methylated samples and the standard were vortexed and applied (3 µl) to the silica plate. After that the TLC plate was placed in the chamber for one hour (with the solvent at the bottom of the chamber). After one hour the silica plate was taken up, and dried by leaning it towards the chamber for approximately 20 minutes. Thereafter the silica plate was put down into a chamber with iodine and then it was left standing there for another 20 minutes. The fatty acid methyl esters were recognized by comparison to the standard TLC mixture.

2.2.4 Gas chromatography (GC)

The fatty acid methyl esters (FAME) of the samples were analyzed in a GC CP-3800 (Varian AB, Stockholm, Sweden) equipped with flame ionization detector (FID) and split injector and fitted with a fused silica capillary column BPX 70 (SGE, Austin, Tex.), length 50 m. id. 0.22 mm, 0.25 µm film thickness. The column temperature was programmed to start at 158°C hold 5 minutes and then increased by 2°C/minute up to 220°C where it remained for 8 minutes. The carrier gas was helium (0.8 ml/minute) and the make up gas was nitrogen. The injector and detector temperatures were 230°C and 250°C respectively. Seven samples were analyzed in duplicates. FAME were identified by comparison with a standard mixture and retention times.

3 RESULTS

3.1 Fat content

The sample with the highest fat content of the seven different samples was the frozen Atlantic salmon fillet bought at ICA and farmed on the Faroe Island (Figure 1). The different sample names in the figure below all have different brands and have been farmed at different places, accept Salmon 5 which is captured from the wild (Table 3).

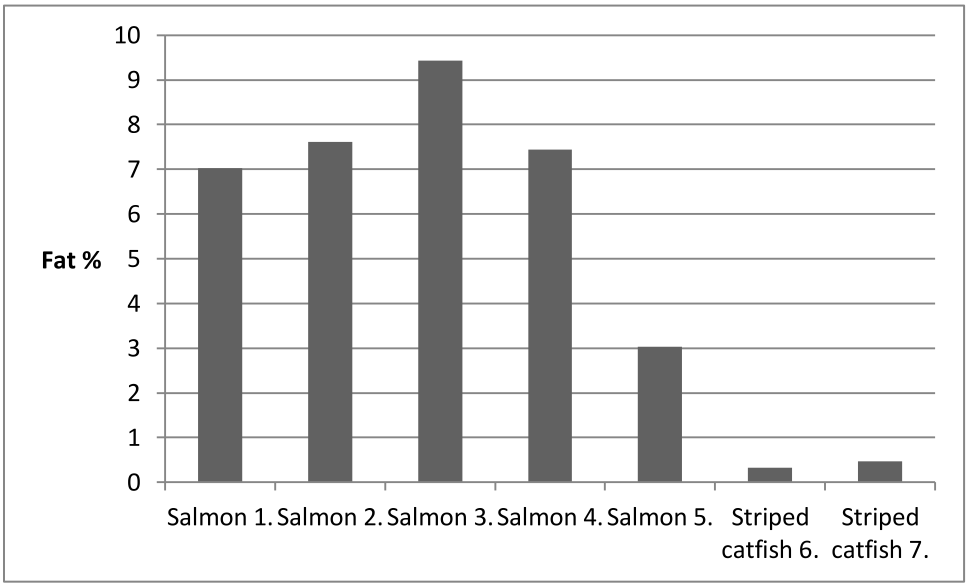

Figure 1. The fat content of analyzed samples, numbers of samples are explained in table 3.

3.2 Fatty acid composition

The fatty acid composition of all the different samples is shown in table 4.

Table 4. Fatty acid composition of different Atlantic salmon samples (% of total fatty acids), numbers of samples is explained in table 3.

	Salmon 1.		Salmon 2.		Salmon 3.	
Fatty acid	Mean	SD	Mean	SD	Mean	SD
14:0	1.98	0.02	2.21	0.00	3.23	0.01
14:1	0.04	0.00			0.09	0.00
16:0	9.88	0.02	10.5	0.04	10.3	0.07
16:1 (n-7)	2.05	0.09	2.53	0.08	3.59	0.02
17:0	0.20	0.00	0.17	0.03	0.16	0.01
17:1	0.07	0.00	0.08	0.01	0.10	0.00
18:0	2.61	0.02	2.74	0.04	2.32	0.02
18:1 (n-9)	39.9	0.09	39.1	0.60	31.5	0.42
18:1 (n-7)	3.22	0.04	3.16	0.02	3.23	0.05
18:2 (n-6)	13.2	0.02	12.3	0.00	9.24	0.17
18:3 (n-6)	0.05	0.00			0.06	0.02
18:3 (n-3)	4.92	0.00	4.43	0.06	3.84	0.03
20:0	0.36	0.00	0.32	0.01	0.26	0.00
20:1 (n-9)	4.04	0.00	4.41	0.13	6.88	0.09
20:1 (n-7)	0.14	0.00	0.14	0.00	0.24	0.00
20:2 (n-6)	1.07	0.00	1.11	0.01	0.90	0.02
20:3 (n-6)	0.22	0.00	0.29	0.00	0.15	0.00
20:4 (n-6)	0.26	0.01	0.27	0.02	0.35	0.14
20:3 (n-3)	0.45	0.00				
22:0	0.19	0.00	0.16	0.02	0.12	0.00
22:1 (n-11)	3.05	0.01	3.41	0.09	7.36	0.03
22:1 (n-9)	0.66	0.00	0.59	0.00	0.91	0.01
20:5 (n-3)	2.76	0.00	2.85	0.03	3.18	0.17
24:1	0.39	0.01	0.40	0.01	0.59	0.02
22:5 (n-3)	1.21	0.02	1.51	0.00	1.60	0.04
22:6 (n-3)	4.87	0.13	4.62	0.00	6.09	0.55
SFA	15.2	0.02	16.1	0.06	16.4	0.07
MUFA	53.5	0.16	53.8	0.71	15.5	0.54
PUFA (n-3)	14.2	0.15	13.4	0.08	14.7	0.73
PUFA (n-6)	14.8	0.03	14.0	0.01	10.7	0.31
n3/n6	0.96	0.01	0.96	0.01	1.38	0.11
Totally identified	95.0	0.01	94.5	0.56	93.1	0.05

Table 4 cont. Fatty acid composition of Atlantic salmon (Salmon 4) and pink salmon (Salmon 5) samples (% of total fatty acids), numbers of samples is explained in table 3.

	Salmon 4.		**Salmon 5.**	
Fatty acid	Mean	SD	Mean	SD
14:0	2.20	0.02	4.19	0.01
14:1	0.06	0.00	0.17	0.01
16:0	9.33	0.34	15.8	0.25
16:1 (n-7)	2.23	0.03	4.68	0.11
17:0	0.20	0.00	0.32	0.02
17:1	0.08	0.00	0.11	0.06
18:0	2.34	0.06	2.89	0.07
18:1 (n-9)	39.3	0.18	12.9	0.42
18:1 (n-7)	3.05	0.02	1.92	0.01
18:2 (n-6)	13.5	0.27	1.26	0.02
18:3 (n-6)	0.06	0.00	0.41	0.03
18:3 (n-3)	5.24	0.13	1.46	0.01
20:0	0.33	0.01		
20:1 (n-9)	4.21	0.04	2.39	0.15
20:1 (n-7)	0.14	0.00	1.17	0.09
20:2 (n-6)	0.95	0.01	0.56	0.01
20:3 (n-6)	0.18	0.01	0.10	0.00
20:4 (n-6)	0.25	0.01	0.37	0.01
20:3 (n-3)	0.39	0.00	0.24	0.01
22:0	0.16	0.01		
22:1 (n-11)	3.53	0.01	7.47	0.38
22:1 (n-9)	0.66	0.02	0.75	0.05
20:5 (n-3)	2.79	0.00	10.8	0.46
24:1	0.37	0.01	0.39	0.05
22:5 (n-3)	1.08	0.00	3.51	0.01
22:6 (n-3)	4.88	0.28	15.9	1.47
SFA	14.6	0.37	23.2	0.18
MUFA	53.6	0.20	31.9	1.19
PUFA (n-3)	14.4	0.16	31.9	1.90
PUFA (n-6)	14.9	0.28	2.69	0.00
n3/n6	0.97	0.03	11.9	0.72
Totally identified	94.7	0.05	89.7	0.89

Table 4 cont. Fatty acid composition of different striped catfish samples (% of total fatty acids), numbers of samples is explained in table 3.

	Striped catfish 6.		**Striped catfish 7.**	
Fatty acid	Mean	SD	Mean	SD
14:0	2.47	0.19	3.15	0.01
14:1				
16:0	26.4	0.38	30.1	0.03
16:1 (n-7)	0.58	0.03	0.81	0.02
17:0	0.16	0.01	0.18	0.01
17:1			0.07	0.01
18:0	7.82	0.06	7.68	0.01
18:1 (n-9)	27.9	1.17	33.7	0.36
18:1 (n-7)	1.12	0.01	0.88	0.03
18:2 (n-6)	8.74	0.11	8.52	0.03
18:3 (n-6)	0.22	0.00	0.27	0.00
18:3 (n-3)	0.29	0.02	0.33	0.00
20:0	0.11	0.01	0.15	0.01
20:1 (n-9)	1.37	0.08	1.22	0.02
20:1 (n-7)	0.06	0.00	0.05	0.00
20:2 (n-6)	0.85	0.04	0.57	0.02
20:3 (n-6)	2.87	0.19	1.52	0.05
20:4 (n-6)	5.14	0.43	1.37	0.16
20:3 (n-3)				
22:0				
22:1 (n-11)				
22:1 (n-9)				
20:5 (n-3)	0.29	0.01	0.26	0.01
24:1				
22:5 (n-3)	0.76	0.07	0.47	0.02
22:6 (n-3)	3.53	0.27	2.75	0.16
SFA	36.9	0.48	41.3	0.04
MUFA	31.1	1.27	36.8	0.44
PUFA (n-3)	4.87	0.33	3.81	0.19
PUFA (n-6)	17.8	0.54	13.5	0.25
n3/n6	0.27	0.01	0.28	0.01
Totally identified	90.7	0.96	94.1	0.02

To make it easier to see the differences between the content of the two essential fatty acids linoleic acid (18:2 n-6) and α-linolenic acid (18:3 n-3), and the fatty acids EPA (20:5 n-3) and DHA (22:6 n-3), a comparison is present in Figure 2. A significant difference between salmon sample 5 and the rest of the samples, is the high proportion of EPA and DHA in salmon 5.

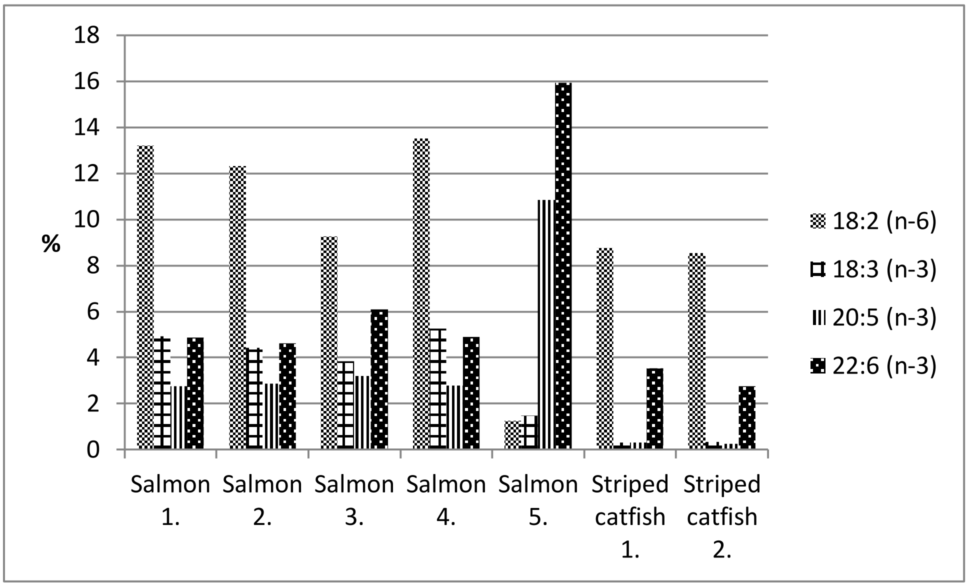

Figure 2. Content of 18:2 (n-6), 18:3 (n-3), 20:5 (n-3) and 22:6 (n-3) in all the samples (% of total fatty acids).

The proportion of SFA in the salmon samples were lower than in the striped catfish samples (where SFA had a higher proportion), the PUFA (n-3) has the opposite state with lower proportion in the striped catfish and higher proportion in the salmon samples. The proportion of PUFA (n-6) was rather the same in all the samples accept in sample 5, where it was lower. The MUFA proportion was higher in the salmon samples 1-4, but lower in the salmon sample 5 and striped catfish samples 6 and 7 (figure 3).

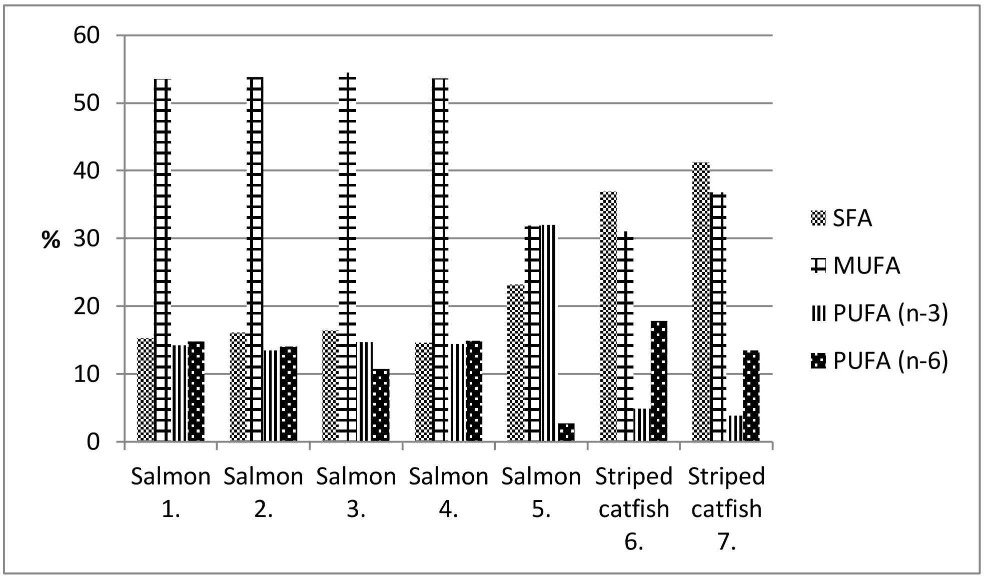

Figure 3. Content of SFA, MUFA, PUFA (n-3) and PUFA (n-6) in all samples (% of total fatty acids).

A comparison between all the samples regarding the difference in the n3/n6 ratio is presented in Figure 4. A very significant difference was observed between salmon 5 and all the other samples. It was a minor difference between the salmon samples and the striped catfish samples, where the n3/n6 ratio in the striped catfish samples was lower.

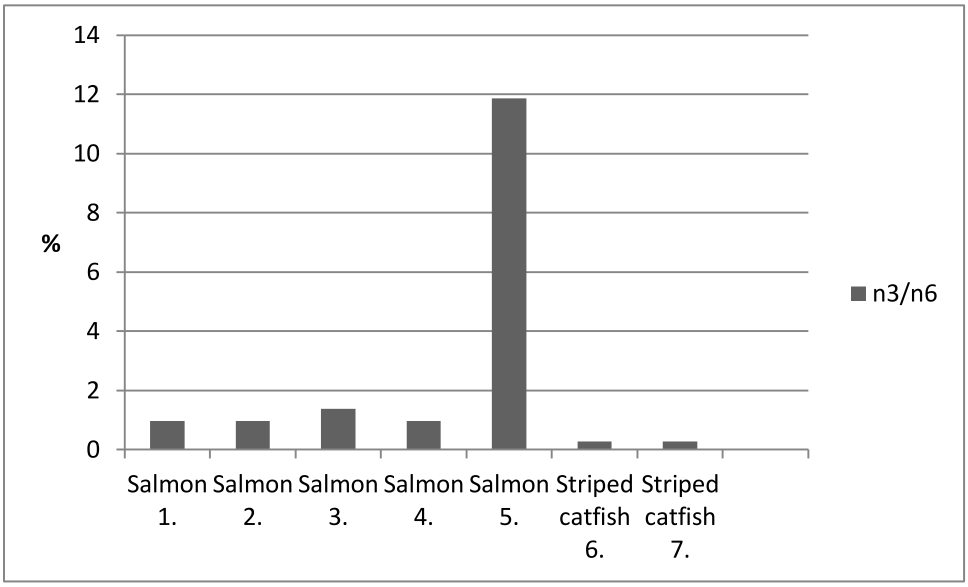

Figure 4. The n3/n6 ratio of all the samples (% of total fatty acids).

Table 5 shows the content of EPA, DPA and DHA in the different fish samples, to be compared with values from SLV and NIFES (Tables 1-2).

Table 5. EPA, DPA and DHA in farmed Atlantic salmon (Salmon 1-4) and wild pink salmon (Salmon 5) (g/100g fish), numbers of samples are explained in table 3.

Fatty acid	**Salmon 1.**	**Salmon 2.**	**Salmon 3.**	**Salmon 4.**	**Salmon 5.**
20:5 (n-3)	0.2	0.2	0.3	0.2	0.3
22:5 (n-3)	0.1	0.1	0.2	0.1	0.1
22:6 (n-3)	0.3	0.4	0.6	0.4	0.5

Table 5 cont. EPA, DPA and DHA in farmed striped catfish (g/100g fish), numbers of samples are explained in table 3.

Fatty acid	**Striped catfish 6.**	**Striped catfish 7.**
20:5 (n-3)	0.0	0.0
22:5 (n-3)	0.0	0.0
22:6 (n-3)	0.0	0.0

4 DISCUSSION

4.1 Fatty acid composition

Fatty fish like salmon is a great source of EPA (20:5 n-3) and DHA (22:6 n-3), and that is the reason why the proportion is higher in Atlantic salmon and pink salmon than in the striped catfish (Fleming, Harris & Kris-Etherton 2011)

The high percentage of EPA and DHA in the wild pink salmon, is the major reason why there is a high n-3 to n-6 ratio in the wild pink salmon. This was stated in a study by Heintz et al (2004), and they claim that a high amount of EPA and DHA can give a high n-3 to n-6 ratio in marine fish species. In the aquatic food web (food chain) the EPA and DHA is acquired directly from the plants (Brett & Müller-Navarra 1997), and then ends up in the predatory fish. The marine algae and fungi are the main creators of n-3 PUFA through the marine food chain (Sijtsma & Swaaf 2004).

The essential fatty acid α-linolenic acid (18:3 n-3) is present in all the samples of salmon and striped catfish, but in different proportions. α-linolenic acid has a smaller proportion in striped catfish than in the Atlantic salmon and pink salmon. It has been proved that fish from freshwater contain a lower percentage of n-3 PUFA than marine fish (Ozogul & Ozogul 2007). This could be the reason why the n-3 fatty acid α-linolenic acid is present in a smaller percentage in the freshwater fish striped catfish.

Caproni et al (2008) found during their research that linoleic acid (18:2 n-6) made up as much as 44-59 % of the total PUFA in the sutchi catfish fillet (another word for striped catfish), but that also arachidonic acid (20:4 n-6) and docosahexaenoic acid (22:6 n-3, DHA) were prevalent PUFA in the sutchi catfish fillets. The PUFA were present in the sutchi catfish fillet at a low percentage. This conclusion is confirmed in this paper, were the striped catfish had a high percentage of linoleic acid.

One difference concerning linoleic acid is that in the wild pink salmon the proportion of linoleic acid is smaller compared to striped catfish and farmed Atlantic salmon where it is higher. This difference could depend on the different diet these fishes will eat. Probably the farmed striped catfish and farmed Atlantic salmon have been fed a diet higher in vegetable oil. Pan (2013) in his study found that the n-3 PUFA in rapeseed oil, linseed oil and soy oil are mostly build up by C18 PUFA like the two fatty acids α-linolenic acid and linoleic acid. This could be a reason for linoleic acid being high in farmed striped catfish and farmed Atlantic salmon in this paper. According to El-Sayed (2006) it is generally known that marine fish and cold-water fish needs a diet with n-3 polyunsaturated fatty acids, when the freshwater fish which lives in warm waters tend to need n-6 polyunsaturated fatty acids. This could be an explanation to why the linoleic acid (18:2 n-6) is higher in the freshwater fish striped catfish than in wild pink salmon. In this paper the farmed striped catfish had a higher percentage of n-6 PUFA and a lower percentage of n-3 PUFA.

The SFA 16:0 were significantly lower in the salmon (both farmed and wild) samples compared to the striped catfish samples, also the saturated fatty acid 18:0 has a lower proportion in the salmon samples. A difference is the saturated fatty acid 20:0, which is higher in the salmon samples than in the striped catfish. According to an article from 1987 written by Henderson and Tocher the lipids in freshwater fish contain a higher proportion of SFAs and C18 PUFA, but a lower level of C20 and C22 unsaturates, than the lipids in marine fish. This result could be an explanation to the high percentage of SFA in the freshwater fish striped catfish in this paper. Also the C18 PUFA linoleic acid is high in striped catfish compared to α-linolenic acid which is lower in striped catfish. The level of C22 unsaturates (22:5 n-3 and 22:6 n-3) is in this paper a bit lower in the striped catfish than in the marine fish salmon.

The n3/n6 ratio is lower in the striped catfish samples, and higher in the salmon samples. In the article by Hendersson and Tocher (1987) the n-3 to n-6 ratio in the total lipids differed between freshwater fish and marine fish. In freshwater fish the n-3 to n-6 ratio in the total lipid was in the range of 0.5 to 3.8, while in the marine fish it ranged from 4.7 to 14.4. In this paper the freshwater striped catfish had an n-3 to n-6 ratio of approximately 0.3 (a mean value), which is a bit lower than 0.5.The marine Atlantic salmon had an average of 1.1 in the n-3 to n-6 ratio, while the marine pink salmon had an n-3 to n-6 ratio of 11.9 (i.e. in the range of 4.7 to 14.4). A more recent study by Caproni et al (2008) showed that striped catfish fillets had a high proportion of n-6 PUFAs and a low n-3/n-6 ratio, which is common in many freshwater fishes (like striped catfish). This study is in agreement with a low n-3/n-6 ratio in the freshwater fish striped catfish compared to the marine fishes Atlantic salmon and pink salmon. A high proportion of n-6 PUFAs in freshwater fish match up with this paper quiet well, when the n-6 PUFAs have the same proportion in striped catfish as in the salmon samples.

A study by Aliyu-paiko et al (2011) showed that striped catfish, as it is a warm fresh water fish, is fitted to better utilize a diet based on plants. This conclusion shows that the striped catfish more probably had been fed a more plant based diet, and that's why the EPA and DHA have a lower proportion in striped catfish than in Atlantic salmon in this paper.

4.2 Farmed Atlantic salmon versus wild pink salmon

Pan (2013) claims in his study that in today's aquaculture vegetable oil is abundant as a lipid source. By replacing fish oil with plant oil in the fish feed, the result will be a reduction of the EPA and DHA content in the fish fillet (Asche et al 2011). These statements could explain the lower proportion of EPA and DHA in farmed Atlantic salmon compared to wild pink salmon where the amount of EPA and DHA is higher.

In this paper the fat content is lower in the wild pink salmon, compared to the farmed Atlantic salmon were the fat content is higher. In a report from the US, the farmed Atlantic salmon has a permanent higher proportion of EPA and DHA than wild Atlantic salmon, because of the farmed Atlantic salmon´s higher fat content (Fleming, Harris & Kris-Etherton 2011). It can be assumed that wild Atlantic salmon has a similar fat content to wild Pink salmon as it also is a wild salmon. However the proportion of EPA and DHA is higher in wild pink salmon.

Fleming, Harris & Kris-Etherton (2011) found that the wild salmon´s fat content is affected by water temperature around the time of catch, and wild salmon that lives in colder waters store more fat. Another factor that affects the EPA and DHA content and total fat is the age of the wild salmon. All salmon that is caught for human consumption must be approximately two years of age, at which the fat content is higher. These statements made by Fleming, Harris & Kris-Etherton (2011) could be an explanation for the high percentage of EPA and DHA in the wild salmon that has been caught in the Pacific Ocean outside of Canada, which are rather cold waters.

Aursand et al (2009) in a study discovered that wild fish has a low 18:1 n-9 and low 18:2 n-6, while EPA and DHA are high. Another characteristic of wild fish is the high n3/n6 ratio. The low proportion of 18:1 n-9 and 18:2 n-6 in wild fish compared to farmed fish match up with the present results. The high proportion of EPA and DHA in wild fish and the high n3/n6 ratio in wild fish versus farmed fish is seen in the pink salmon in this study.

The farmed Atlantic salmon has a higher percentage of α-linolenic acid than the wild pink salmon. This probably depends on that the farmed Atlantic salmon has been given a diet with an inclusion of vegetable oils, while wild pink salmon has another type of diet that is typical for carnivorous fish (and therefore mostly eat other fish).

An interesting result in a study by Blanchet et al (2005) is that the essential fatty acids α-linolenic and linoleic was three respectively six times higher in farmed Atlantic salmon than in the wild Atlantic salmon. The explanation they give is that it could be the addition of vegetable oils in feeds to farmed Atlantic salmon. This difference in α-linolenic acid is recognized in the present results, where α-linolenic acid is three times higher in farmed Atlantic salmon than in wild pink salmon. Linoleic acid is found to be eleven times higher in farmed Atlantic salmon than in wild pink salmon in this paper.

In vegetable oils there is a high concentration of n-6 and n-9 fatty acids that is mainly linoleic acid and oleic acid (18:1 n-9) respectively (Pettersson 2010). In this paper oleic acid is relatively high in farmed Atlantic salmon and farmed striped catfish, while the wild pink salmon has a lower percentage of oleic acid. This result can depends on the fish feed the farmed Atlantic salmon and farmed striped catfish gets in the aquaculture production. Most probably the farmed fishes get a fish feed partly consisting of vegetable oil, when the wild pink salmon eats what's available in nature as it is a carnivorous fish species.

4.3 Data in this study to be compared to the data available at National Food Administration in Sweden (SLV) and National Institute of Nutrition and Seafood Research in Norway (NIFES)

The data that is available at the National Food Administration in Sweden (SLV 2011) (www, slv.se 1, 2014) for EPA, DPA and DHA in the striped catfish are all zero values. The same results are seen in this study, where the data for EPA, DPA and DHA in the striped catfish is zero. According to the SLV-data (SLV 2013) on farmed salmon from Norway, the values for EPA, DPA and DHA are all higher than the values that have been calculated in this study for Atlantic salmon and pink salmon. This result can depend on that the fishes have been given different kinds of feed, but it is hard to say. The data that is available at the National Institute of Nutrition and Seafood Research in Norway (NIFES) (www, nifes.no 1, 2014) for EPA, DPA and DHA in the Atlantic salmon differs between the years. Between the years 2005 and 2010 there has been a decrease of the EPA, DPA and DHA for the NIFES values, this can be a result of a higher exclusion of fish oils in the farmed Atlantic salmon. In this study the values for EPA, DPA and DHA are significantly lower for farmed Atlantic salmon compared to NIFES. The reason for this can be that today the inclusion of vegetable oils in fish feed is higher than when NIFES published their data.

5 CONCLUSIONS

Interesting results came up with this study, although most of them are already taken up in the scientific literature that is available. Therefore the results in this study could be useful as an additional proof for the already published data in this area. Although it is important to remember that more research is needed, to improve the fish feed in today´s aquaculture. Not only for the cost, but also for a more environmental friendly production.

The n3/n6 ratio can be used to assess the nutritional beneficial effects of food. The n3/n6 ratio is higher in wild pink salmon and lower in farmed Atlantic salmon and farmed striped catfish. Aursand et al (2009) in a study stated that a characteristic of wild fish is the high n3/n6 ratio. The level of EPA and DHA is different in all the samples in this study, but the wild pink salmon has the highest level (this is an explanation to the high n3/n6 ratio seen in the wild pink salmon). It is also important to look at the percentage of PUFA (n-3) and SFA in the food, when PUFA (n-3) are good for health and SFA is less good for the health (www, slv.se 2, 2014). The striped catfish has a higher level of SFA and a lower level of PUFA (n-3) than the Atlantic salmon and pink salmon have. According to an article from 1987 written by Henderson and Tocher, the lipids from freshwater fish contain a high proportion of SFA, but a low proportion of C20 and C22 unsaturates. The fatty acid linoleic acid (18:2 n-6) is in this paper high in the striped catfish, which could depend on the fact that freshwater fish like striped catfish living in warm waters tends to need a diet high in PUFA (n-6) as stated by El-Sayed (2006).

This kind of research is demanded today, since many people in the world gets fatter because of eating not so nutritionally valuable food. Fatty fish is therefore a really good choice, mostly because of the high level of n-3 long chain polyunsaturated fatty acids (especially EPA and DHA) (www, slv.se 3, 2014).

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APPENDIX

POPULÄRVETENSKAPLIG SAMMANFATTNING

Många människor världen över har kännedom om att fisk anses vara hälsosam mat. Det som gör att fiskfett skiljer sig från annat animaliskt fett, är att fiskfett innehåller långa fettsyror med många dubbelbindningar samt många omega-3-fettsyror. De omega-3-fettsyror som är mest förekommande är EPA (eikosapentaensyra) och DHA (dokosahexaensyra). EPA och DHA får fiskarna i sig genom födan. Efterfrågan på foder till fiskarna från fiskuppfödarna (de som odlar fisk i kommersiellt syfte) har ökat genom åren. Däremot har produktionen av fiskfoder stått still. På grund av detta är dagens produktionsnivåer för låga för att möta den stora efterfrågan hos fiskuppfödarna. Tidigare har den odlade fiskens foder mest bestått av fiskmjöl och fiskolja, men i dagens fiskodlingar har en övergång skett till att använda mer av vegetabiliska oljor, detta för att vegetabiliska oljor har relativt stabila priser. Det finns dock motsättningar med att ersätta fiskmjöl och fiskolja med vegetabilisk olja, detta eftersom vegetabiliska oljor inte har samma innehåll av de nyttiga långa fettsyrorna och omega-3-fettsyrorna som fiskmjöl och fiskolja har. Det finns således en efterfrågan på forskning, och nya ersättningar för fiskfödan bör se dagens ljus.

Miljöfaktorer som årstid, genetiskt ursprung, vattentemperatur, diet (fiskföda) och fiskens mognadsgrad påverkar alla näringsinnehållet i fisk. Dessa miljöfaktorer kan manipuleras i en fiskodling, men i det vilda är det svårt. Fettsyrasammansättningen i fisk påverkas avesvärt av lipiderna (fetterna) som finns i fiskfödan.

Syftet med denna studie är att undersöka lipidhalten, lipid och fettsyrasammansättning i Atlantlax (*Salmo salar*) Pinklax (*Oncorhynchus gorbuscha*) och Pangasiusmal (*Pangasius hypophthalmus*). Fiskarna köptes i lokala mataffärer i Uppsala, för att sedan med hjälp av litteraturen beskriva orsakerna till skillnader i fettsyror mellan de tre fiskarterna. Slutligen jämfördes resultaten av undersökningen med tillgänglig data från svenska Livsmedelsverket (SLV) och Norska forskningsinstitutet för näringslära, foder till fisk och fisk som livsmedel (NIFES).

I denna studie togs sju prover sammanlagt från de tre fiskarna Atlantlax, Pinklax och Pangasiusmal. Fiskarna som användes fanns alla tillgängliga i butik i form av filéer (utom en fisk som var i helt tillstånd), och både fryst och färsk fisk användes. Fiskarna hade vidare olika ursprung och märkning. Alla fiskar var odlade utom en som var vildfångad. Alla proverna finfördelades för att kunna användas i vidare analys. Fettsyrorna analyserades kemiskt med hjälp av en gaskromatograf (GC).

Resultaten av denna undersökning verifierar många påståenden som redan har beskrivits i litteraturen. Till exempel visade det sig i denna studie att fetthalten (fettinnehåll) var lägre i den vilda Pinklaxen än i den odlade Atlantslaxen. Ett annat omskrivet resultat är att feta fiskar som Atlantlaxen har ett högre innehåll av EPA och DHA än magra fiskar. En tydlig skillnad i halten EPA och DHA observerades mellan odlad Atlantlax och vild Pinklax, där halten EPA och DHA var högre i den vilda Pinklaxen. Den essentiella fettsyran linolsyra fanns i höga halter i Pangasiusmalen.