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Melanin spots in Atlantic salmon fillets – An investigation of the general problem, the frequency and the economic implication based on an online survey

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Master of Science in Aquaculture

Melanin spots in Atlantic salmon fillets – An investigation of the general problem, the frequency and the economic implication based on an online survey

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Abstract

The appearance of a product is an important quality feature that influences the purchasing decision of consumers. In this respect, dark stained melanin spots in Atlantic salmon fillets have become a major issue in recent years.

The main objective of the thesis was to investigate how the salmon processing industry is rating the problem with fillet melanin spots, and economic implications. The study was based on an online survey that was distributed to the processing industry in Norway, Germany and Poland during October and November 2016. Additionally, a case study was conducted to exemplify utilisation of the survey results. The results of the survey showed that melanin spots together with pale fillet colour are the biggest problems, and that melanin spots appear more frequently compared to other quality issues. On average melanin spots appear in 16.4% of the salmon fillets according to the processing industry, who believe that vaccine and stress are the major causes to the problem. For weak greyish spots and distinct melanin spots up to 3cm the general procedure was to remove only the pigmented tissue (9% average price loss, *PL*). Fillets with larger distinct spots (3-6cm) were generally downgraded (PL for downgrading 26%) whereas fillets with large pigmented areas (>6cm) were generally removed from the food chain (PL 67% on average, modal value 100%). Smaller spots were appearing most frequently; i.e. the bigger the size of the melanin spots, the less frequent occurrence. In the case study (salmon fed two different feeds), results for the economic loss (*EL*) due to melanin spots were used (weak, small melanin spots 8% EL, distinct spots less than 3cm 15% EL, spots 3-6cm 24%, pigment area >6cm 44% EL). It is concluded that melanin spots cause severe economic losses for the salmon processing industry, in particular spots larger than 3cm. Furthermore, it is concluded that the results from the survey can be used to calculate economic implications of melanin spots and economic benefits of reducing the occurrence and severity of melanin spots in salmon fillets.

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1. Introduction

Aquaculture is one of the fastest growing food producing sectors and represents almost 50% of the fish for human consumption. In 2030 aquaculture products are estimated to make up 62% of the share of fish in the human diet and furthermore it has the potential to satisfy the demand of food for the growing human population of the world (FAO, 2014). The latest global statistics collected by Food and Agriculture Organization of the United Nations (FAO) predict a world aquaculture production of 73.8 million tonnes (t) in 2014. The share for the finfish aquaculture was 49.8 million tonnes (t) with an estimated first sale value of US$ 99.2 billion. The world fish aquaculture production rose yearly by 5.8% from 2005-2014 (FAO, 2016b).

Aquaculture is a very diverse sector which is characterized by various practices, culture systems, fish species and environments. The sector has an important role in income generation, employment, food security and nutrition (FAO, 2016).

Atlantic salmon (*Salmo salar L.*) is an increasingly popular species in the aquaculture market. The production of salmon belongs to the most successful commercial intensive aquacultures in the industries. Atlantic salmon is farmed in 16 countries worldwide, with Norway as the largest producer. With approximately 571000 tonnes (t) of salmon product weight and an import value of 2,1billion € the market of the European Union is the largest salmon market in the world (Asche & Bjørndal, 2011).

Therefore, the opinion and preferences of the consumers are of main importance for the aquaculture industry. The fillet quality of the salmon products determine the purchasing decision of the customers (Alfnes et al., 2006). According to Haard (1992) the fat content, texture and the colour of the fish fillets are recognized as major quality parameters. The fish fillet is the most important part of the salmon for the processing industry (Klinkhardt, 2005) and already 25 years ago quality deviations in the fillets like melanin spots, pale and irregular colour, soft texture or gaping were pointed out as major factors causing quality downgrading and economic losses in the industry (Koteng, 1992).

The visual appearance is considered as an important quality characteristic by the salmon farming industry (Kiessling, 2006), as particularly the red fillet colour is of main importance

for the consumers who are willing to pay for intensively red coloured fillets (Anderson, 2001). Dietary supplemented carotenoid pigments, mainly, astaxanthin predominately ensures the desired colour of the salmon flesh (Nickell & Springate, 2001). Discolorations like bloodspots or melanin spots in salmon fillets represent a critical quality problem (Koteng, 1992). In the Atlantic salmon industry, the occurrence of melanin spots in salmon fillets is the major quality issue (Berg et al., 2012).

Melanin is produced by melanocytes and these cells are responsible for the dark pigmentation in the fish fillets (Hearing & Tsukamoto, 1991). It is not clear yet why salmon is producing melanin dark spots, but dark pigmentation in the muscle has been associated with an inflammation (Larsen et al., 2012). A relationship between melanin spots and the occurrence of different diseases is also explored. For example the virus induced pancreas disease (PD) is assumed to stimulate melanin pigmentation in Atlantic salmon (Bjerkeng, 2004, Lerfall et al., 2012). Recently Bjørgen et al. (2015) proposed that the virus piscine orthovirus (PRV), which is related to the heart skeletal muscle inflammation (HSMI), is a premise for the development of melanin spots in salmon skeletal muscle.

Only a few studies have been performed to identify means to reduce melanin spots in Atlantic salmon, but a reduction in size and presence of dark spots was documented in salmon by adding supplemented feed with antioxidants (vitamin C, E and selenium) (Wang, 2016).

It is an overall goal of the salmon industry to produce fish with superior flesh quality. In order to achieve this goal, it is important to know the industry's opinion about the various quality problems in salmon fillets and the economic impacts of them. Until now, no research is known in which the processing industry was surveyed about the general quality problems, especially melanin spots and their economic influence. To generate new information in this area and to support future research to achieve the overall goal, the objectives of this study are:

a. to record and analyse the general problem, the prevalence and economic implication of melanin spots in Atlantic salmon fillets by using an online based questionnaire intended for the processing industry.
b. to obtain the results of the survey in a case study to exemplify utilisation of the collected data.

In order to achieve the two objectives a. and b., the results were processed and used in the following sequence (Figure 1).

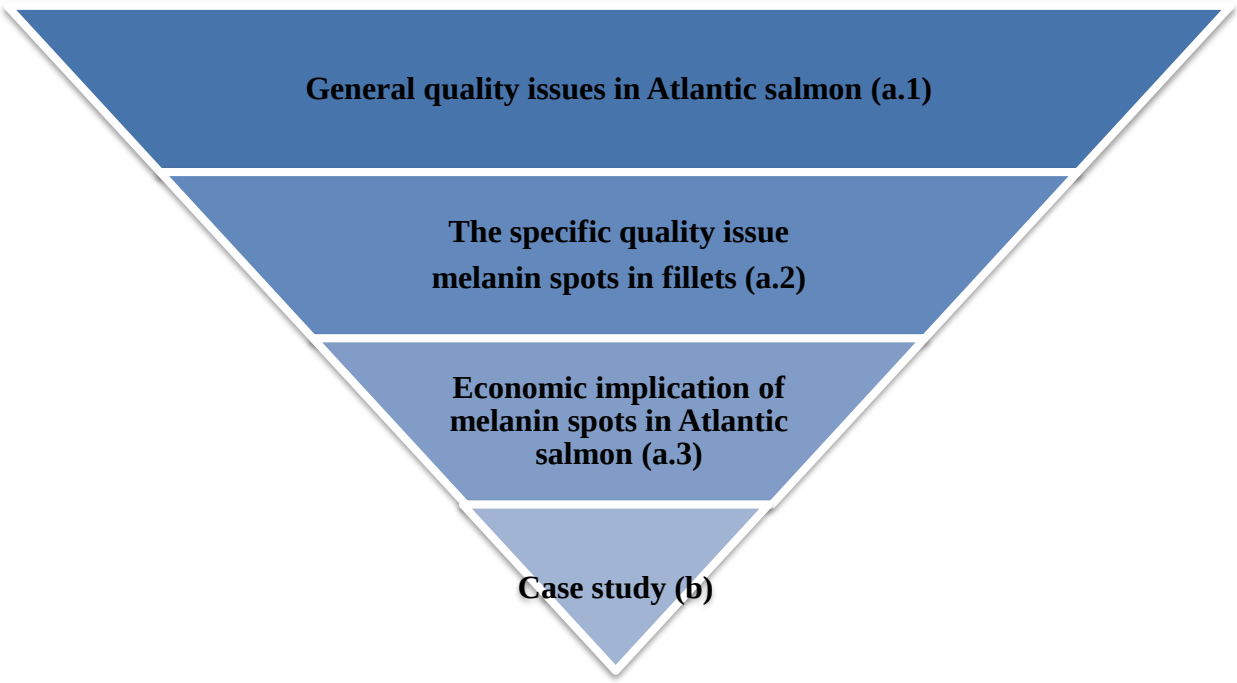


Figure 1: The different sequences that were considered to reach the two objectives.

2. Theoretical background

2.1. Atlantic salmon (*Salmo salar L.*)

The global production of Atlantic salmon was 1.433.708 t in 2007 and represents 4.5% of the total fish production in aquaculture. Worldwide 16 countries produce this species in aquaculture (Klinkhardt, 2010). Atlantic salmon is an anadromous fish, that is hatched in freshwater where they live during their juvenile phase before they migrate to saltwater to the feeding grounds and return to freshwater for spawning (Verspoor et al., 2008). The fully closed and controlled production cycle of Atlantic salmon in captivity began in Norway in the 1960s. They were the first that were able to produce salmon to market size in net cages, located in the fjord arms of Norway. A decade later other countries started as well and Iceland sold the first market sized Atlantic salmon in 1975 followed by Faroe Islands in 1976 and Canada in 1979 (Klinkhardt, 2010). Market size means that the salmon is slaughtered at a weight of 3kg or higher (Neudecker et al., 2009).

The optimal temperature range for growth of salmon is between 12°C and 15°C (Stead & Laird, 2001). The whole Atlantic salmon aquaculture production cycle takes approximately three years (Naylor et al., 1998). The production cycle and the technology are based on the natural life cycle (Klinkhardt, 2010). Gross (1998) divides the production cycle into four steps. The first step is the production of brood stock. Hatchery is step two and production of smolts step three. The last step is the grow-out phase. The last step has the highest market relevance. (Asche & Bjørndal, 2011). Most of the Norwegian salmon that is produced today is the offspring of about 40 different parental wild salmon populations established decades ago. Since then different family lines have been developed through several breeding programmes. Major traits that have been focused include good growth, food conversion rate, high disease resistance and fillet quality (Klinkhardt, 2010).

2.2. Salmon market and trade

The importance of aquaculture in human food production and consumption has increased over the years (Smith et al., 2010). Especially the salmon production sector with its expertise, innovation and the expanding knowledge of production technologies, is a continuously growing industry (Asche & Bjørndal, 2011; Aslesen, 2009).

Salmon aquaculture takes place nearly on all continents. Salmon trout, Coho and Atlantic salmon are the most produced salmon species. Atlantic salmon is the species with the highest

output per year and importance regarding profit (Asche & Bjørndal, 2011). In Europe 1.56 million tonnes (t) of Atlantic salmon were produced in 2015 (FEAP, 2016a).
The biggest producers of Atlantic salmon in the world are Chile and Norway (Figure 2), with a total production of approximately 82% of all Atlantic salmon in 2014 (FAO, 2017).

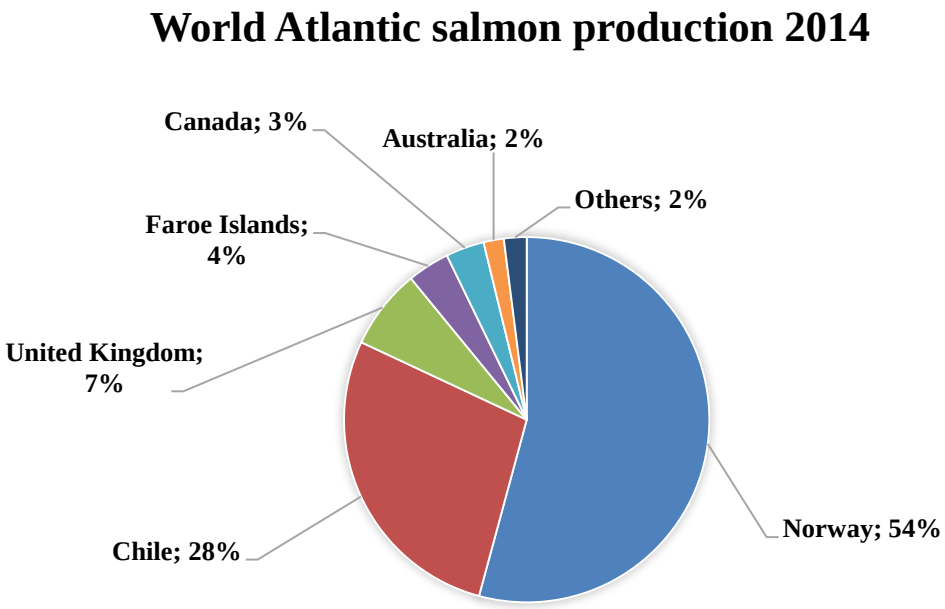


Figure 2: Total aquaculture production of 2.33 million tonnes of Atlantic salmon 2014 (FAO, 2017)

Chile is mostly selling their produced salmon to Asia, USA and South America, whereas Canada mainly exports to the USA, and Scotland mostly trades salmon within the EU (Asche & Bjørndal, 2011). Norway's most important market of Atlantic salmon is the European Union (Johnsen & Nilssen, 2001), but Norway also exports a substantial amount to Russia and Japan (Asche & Bjørndal, 2011).

The European Union is the biggest single salmon market in the world (Asche et al., 2007), consuming approximately 571000 tonnes (t) of salmon product weight at an import value of 2,1billion €. The European market is seen as heterogeneous, because of the different traditions and quantities of seafood consumption per country (Asche & Bjørndal, 2011). For example, the seafood consumption in kilogram per capita of Switzerland (19) is low compared to Portugal (57.1), which had the highest consumption in Europe in 2013 (NSC, 2014). Poland

instead is establishing a market for processing seafood with especially Norwegian Atlantic salmon (Asche & Bjørndal, 2011).

The structure of the market and the associated value chain of salmon is illustrated in Figure 3. The price of a product can be calculated for each step of the value chain by combining all the input costs and the part the company put on as a profit (Bostock et al., 2016).

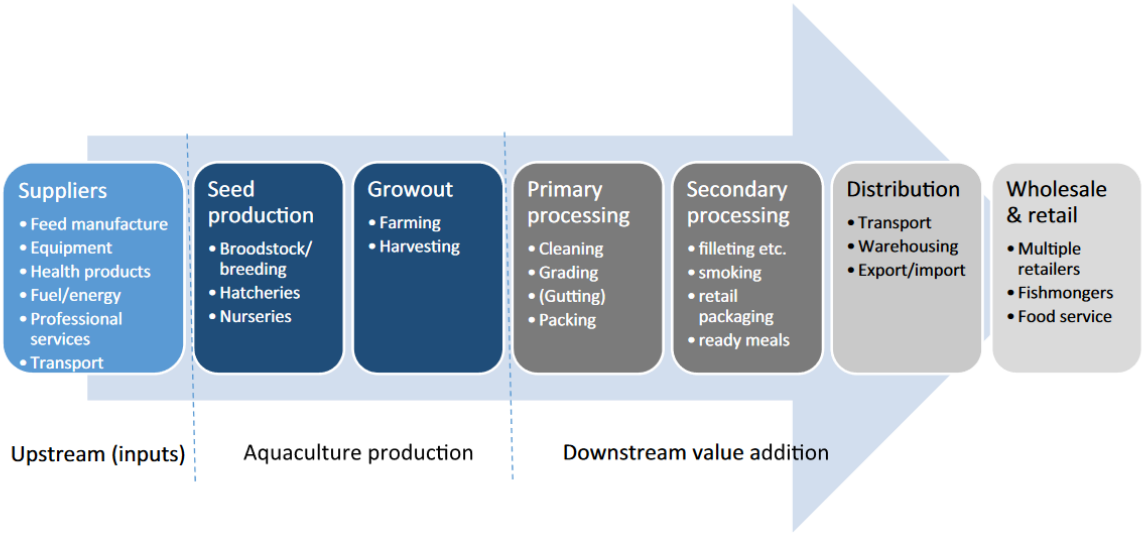


Figure 3: General value chain structure (Bostock et al., 2016)

The value chain of salmon is quite complex compared to for example shellfish. Shellfish compared to salmon is not really processed after substantive processing. The value chain of salmon can be divided in three parts.

- The first part is the upstream, also called input, that includes for example the feed manufacturing.
- The second step is the production of the salmon itself, which includes the whole production lifecycle.
- The last part is downstream value addition. This last step includes slaughtering as well as the more specific processing, like smoking, and the distribution of the product to the different places where finally wholesalers and retailers sell the product to the consumer market (Bostock et al., 2016).

For this thesis, only the aquaculture production and especially the downstream value addition are of interest.

2.2.1. Norway

Since the 1970´s the aquaculture production in Norway has developed to an industry with high performance that can compete with the fishery industry. Atlantic salmon is the major species, but Norway is also farming trout, halibut and scallops. Norway had 4.8 million inhabitants with a per capita consumption of seafood of 22.9kg in 2006. Norway has good environmental conditions for farming salmon like stable water temperature (from 4C° up to 15C°) in the fjords, at the coastlines and in inlets (Asche & Bjørndal, 2011). Also, the good infrastructure is one of the reasons for its important role in the world's salmon production. (Asche & Bjørndal, 2011).

The development of Atlantic salmon production in Norway and other European countries is illustrated in Figure 4. Norway produced nearly 1.3 million tonnes (t) of Atlantic salmon in 2015(FEAP, 2016b).

PRODUCTION (tons)		YEAR								
SPECIES	COUNTRY	2007	2008	2009	2010	2011	2012	2013	2014	2015
Atlantic salmon	NORWAY	751,000	799,000	870,000	941,001	1,023,000	1,240,000	1,195,000	1,290,000	1,301,000
	UTD. KINGDOM	129,930	129,545	142,283	147,412	150,000	162,223	162,234	163,347	186,508
	FAROE ISLANDS	22,300	38,800	51,500	45,400	60,400	76,800	76,480	86,449	66,090
	IRELAND	11,000	10,000	12,500	12,500	12,000	12,000	11,000	10,000	11,000
	ICELAND	1,158	292	714	1,068	1,083	2,923	3,018	3,965	3,220
	FRANCE	1,800	0	0	802	700	300	300	300	300
Atlantic salmon Total		917,188	977,637	1,076,997	1,148,183	1,247,183	1,494,246	1,448,032	1,554,061	1,568,118

Figure 4: Development in Atlantic salmon in tonnes 2007-2015 (FEAP, 2016b)

Main reasons for raised profitability in Norwegian salmon farming are due to lower mortality rates, new technologies in feeding procedure, disease control and shortened production cycle due to light and temperature manipulation in the on growing phase. These modifications also lead to reduced average production costs. Compared to Scotland, the production cost in Norway is approximately 0,1-0,3€ lower. Chile, as the second largest Atlantic salmon producers, has lower production costs than Norway, but the infrastructure is not as good as in Norway and therefore Chile has to deal with higher transport costs (Asche & Bjørndal, 2011).

In 2008 Norway had 1.276 permissions for salmon and trout aquacultures (285 smolt productions, 916 on growing farms, 28 for keeping the generation of parents and 47 for research and development reasons).

The Norwegian seafood industry is export orientated and trades with over 150 countries (Klinkhardt, 2010). The most important trading partner for Norway is the EU (Asche &

Bjørndal, 2011), and most of the salmon from Norway are exported as frozen, fresh and chilled whole fish (FAO, 2011).

2.2.2. Germany

With approximately 82 million inhabitants and high consumption of food, Germany is a very interesting partner for food trading. The economy is stable in comparison to the global market (Johnsen & Nilssen, 2001). The market for seafood and fish consumption in Germany is stable and there is a rising willingness of the consumer to pay for fish and seafood products (FIZ, 2016). Over half of the Germans (54%) eat fish at least once a week and Germany had a per capita consumption of 14.8kg in 2013 (NSC, 2014). The Fischerei Informations Zentrum e.V. (FIZ) (2016) refers to the Gesellschaft für Konsumforschung (GfK) which discovered that the consumer expenditures for fish increased in 2015 by 3.1 % to 3.7 billion € compared to 2014. Referring to the earlier explained value chain of fish, the different steps in Germany have different market shares. The fish industry in Germany is successful in selling products abroad and exported 980 tonnes (in 1000 tonnes) in 2014. In 2015 Germany had 52 fish processing companies with more than 20 employees. Imports with a volume of 1.87 million tonnes and a share of 87% continue to be of the greatest importance for the fish supply of the German market. The imports are supplemented by self-production, which is made up of the self-landings of fish by German fishermen and of German inland fishing and aquaculture. These revenues rose to 273,000 tonnes in 2015 (FIZ, 2016).

Germany is after France the biggest importer of salmon in the EU (Asche & Bjørndal, 2011). Germany is importing Atlantic salmon as well as Pacific wild salmon, but the Pacific wild salmon is no competition for the suppliers of farmed Atlantic salmon, since it can offer a regular delivery and good quality (Johnsen & Nilssen, 2001).

Since the 90´s the demand for whole fresh Atlantic salmon did not increase compared to the demand of other Atlantic salmon products like fillets (Asche & Bjørndal, 2011). Salmon fillets become more interesting for the German market (Johnsen & Nilssen, 2001) and especially the import of frozen fillets became more important. (Asche & Bjørndal, 2011).

Even though Norway is the largest supplier of Atlantic salmon for Germany, the value-added products like smoked salmon are mostly processed in a third country like Poland. This is visible in the approximate amount of 22000 tonnes (t) smoked salmon imported to Germany. Poland took the lead from Denmark in processing salmon and exporting it to Germany.

Germany itself has a few processing companies that produce value added products of fresh raw material, which is mostly imported from Norway (Asche & Bjørndal, 2011, FIZ, 2016).
In Germany salmon is offered and consumed nearly everywhere; as frozen portions of salmon in supermarkets, as meals in restaurants or prepared at home for the family (NSC, 2014). The only change in the demand of salmon is that consumers are more and more concerned about the production processes, the origin of the product, the diversity of the product and even more important for the consumer is the quality of the product. Therefore, the consumption of organic salmon is slightly increasing (Asche & Bjørndal, 2011).
Since prices are determining the consumption behaviour in Germany, low salmon prices in Germany can be seen as a future chance for increasing sales (Asche & Bjørndal, 2011).

2.3. Salmon products

Salmon is available throughout the year and has a great potential for value adding (Klinkhardt, 2005). In order to meet the individual requirements of the consumers, the salmon has to be further processed after slaughtering (Shaw & Muir, 1987). The interest of the value adding industry in this high quality and versatile fish is constantly growing. The number and quantity of salmon products is rising every year (Klinkhardt, 2005). Some producers process the fish directly in their own company, while others relocate it to different processing companies (Shaw & Muir, 1987). Only a small part of the salmon is processed in the country where it is farmed, e.g. only 15% of salmon farmed in Norway is processed in the country itself (Klinkhardt, 2005).
Because of the further processing of salmon, the product value more than doubles and makes the product in this stage important product for the economy, the performance in this level of the food chain has a high impact on the fish industry in total (Shaw & Muir, 1987).

Processing can be divided into primary and secondary processing (Knapp et al., 2007).
Michie (2001) propose the following definitions of primary and secondary processing of fish products:

- Primary processing is the preparation prior to the distribution to the next food chain and includes the evisceration, cleaning and weighing.
- Secondary processing means “removal of the meat from the skeletal frame and preparation of the product for final presentation to the consumer, transformed into either the ready or to eat or ready to cook form”.

The products that have been processed secondarily are called value-added products (VAP) (Venugopal, 2005). The FAO (2016a) divides the different products into frozen, smoked and fresh.

The fillet is the most important raw and intermediate product in the salmon processing industry (Klinkhardt, 2005). Filleting means the removing of the fish bones and the spine by separating inedible and edible parts of the fish manually or by machine (Rørå et al., 2001). The fillets can be further trimmed, and the higher the degree of trimming and bone removal, the higher the price of the fillet (Klinkhardt, 2005) .

Import of processed and unprocessed salmon products to the European countries is mainly comprised of whole, fresh salmon (64%) but fresh and frozen fillets also comprise a large part (30%) (Figure 5).

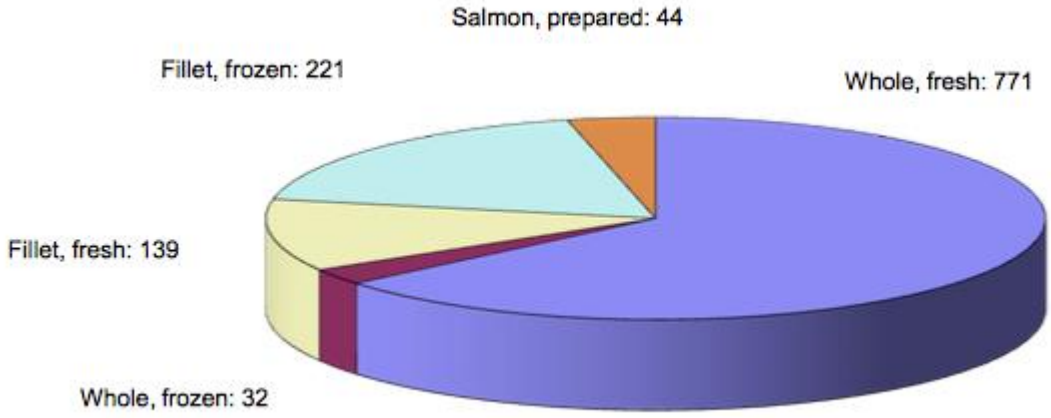


Figure 5: The volume (1000 tonnes) of unprocessed and processed salmon imported into EU from third countries in 2014 (AIPCE-CEP, 2015)

Smoked salmon is belongs to other value-added products as one of the most common products in Europe and especially in Germany it is known as a typically fish product for breakfast (MarineHarvest, 2016, NSC, 2014). The figure below illustrates the estimated market of smoked salmon in the EU 2015 (Figure 6). It shows the percentage of the market share for smoked salmon in the different countries in 2015. The figure clarifies that Germany with 25% followed by France with 21% are the main markets for this value-added product.

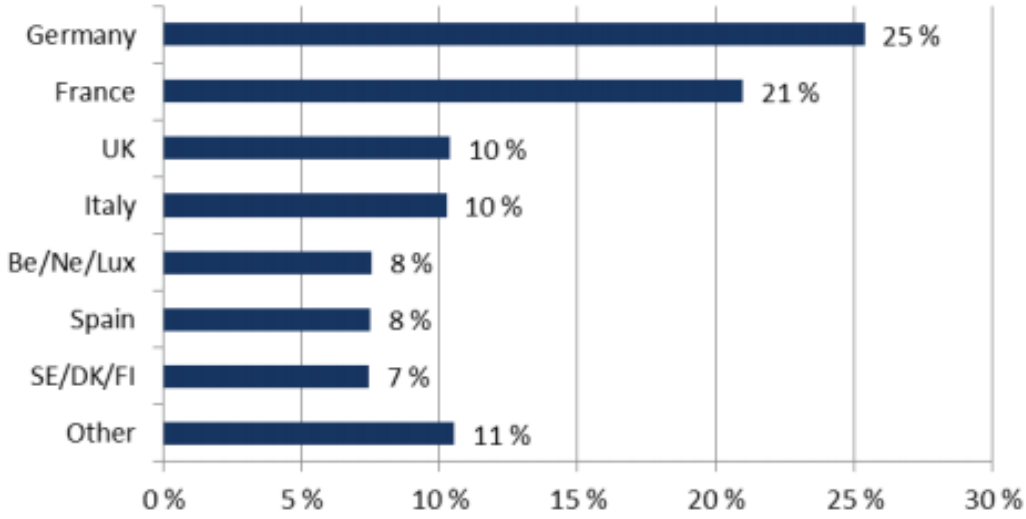


Figure 6: European smoked salmon market share in 2015 (MarineHarvest, 2016)

2.4. Quality

The quality of a food product is important for the consumers. Not only the taste of a product leads them to buy it, but also the health issue, like fat content, and the way of production, e.g. ecological production, influences the purchase decision (Frewer & Van Trijp, 2006).

The processing industry benefits from high product quality of farmed salmon due to lower product losses and as a result higher profitability and access to innovative marketplaces. Quality can be divided in primary and secondary quality. Primary quality includes the biological quality, the educated production and management and the product quality. The biological quality includes the health status, the species, the size of the product and the season; whereas product quality means the ethical, sensory, hygienic, nutritional and technological quality. Secondary quality is described as perceived quality and market quality (Thomassen et al., 2007).

The consumer's opinion on quality and which parameters are the most important for them is of interest for the aquaculture producers. The purchasing decisions of consumers depend on the quality of a product (Alfnes et al., 2006). According to Koteng (1992) the appearance of the gills, texture, colour, fat content and freshness are key factors for the product quality on the market. Quality deviations can lead to downgrading in the secondary processing of the product and associated economic loss can be substantial (Koteng, 1992, Michie, 2001). Melanin spots in the salmon flesh, pale colour, gaping, soft flesh and deformities are typical quality deviations in the secondary processing (Koteng, 1992). Quality deviations can have

different causes, including biological changes in the different seasons like changes for maturation, wrong handling after harvesting and in the processing or the production circumstances and growth history can be causes for it (Michie, 2001).

Fat content

The fat content in salmon can influence the colour as well as the texture and flavour. The fat content of ready to slaughter salmons varies in within the same population (Mørkøre, 2001). The feed, the amount of the feed offered and the season influences the fat content in adult farmed salmon (Mørkøre & Rørvik, 2001). About 80% of the muscle weight in a healthy sexually immature salmon is comprised of water and fat (Haard, 1992). In winter time the fat content in the muscles is generally lower than in autumn (Mørkøre & Rørvik, 2001). A report from Stead & Laird (2001) published that the aquaculture farmed salmons have a higher amount of fat content compared to years ago. The innovation in the feeding industry and higher technical and health standards for the fish are reasons for the higher fat content and therefore for higher quality standards (Einen et al., 1999).

Gaping

Michie (2001) explains that gaping is a result of damage to the connective tissue that holds the muscle blocks together. Therefore, gaping is seen as visible cracks in the fillet. Fillet gaping is a quality issue that can cause downgrading of salmon fillets (Michie, 2001).
This visual damage can make it difficult to sell and to process the fillet further e.g. skinning (Kiessling et al., 2004). Gaping can be seen as a post mortem occurrence (Lavéty, 1980) as a consequence of muscle tension and contraction after the slaughtering (Michie, 2001). The seasonal variation, the secondary process, e.g. smoking, as well as the slaughtering method and the temperature post mortem influences this quality deviation, also freezing the fish and the different handlings can affect gaping (Lavéty, 1980). Sometimes gaping is related to soft texture, but it can also appear in firm flesh (Mørkøre & Rørvik, 2001).

Texture

For the sensory quality the texture of fish fillets is an important issue (Coppes-Petricorena et al., 2010). Consumers prefer salmon with firm (Merkin et al., 2014) and juicy flesh instead of dry flesh. The content of intra muscular fat and the amount of moisture determine the juiciness of the flesh (Ofstad et al., 1996). The texture characteristic can be determined by tasting by the mouth or by touching with the fingers (Hyldig & Nielsen, 2001). Compared to

land based domesticated farm animals, fish has a softer texture because of the lower content of collagen (Liu et al., 2013).

The texture is influenced by different parameters. Ante-mortem the texture quality can for example be influenced by seasonal variations (Mørkøre & Rørvik, 2001), starving of the fish before slaughtering (Einen et al., 1998, Mørkøre, 2008, Mørkøre et al., 2008), genetic background (Bahuaud et al., 2010), the photoperiod regimes, the season of harvesting and the fish species (Johnston et al., 2004, Hagen et al., 2007, Espe et al., 2004).

Post mortem, texture is influenced by rigor development, the level of proteolysis and the pH extent and level (Coppes-Petricorena et al., 2010). Fast growth of the fish can lead to soft texture in fillets as well (Mørkøre & Rørvik, 2001).

Colour

A customer's decision to buy a fish product is 40% based on the colour of the product (Robb, 2001b). Red colour in salmon products is preferred to lighter red and more yellow colour (Skonberg et al., 1998). The red/pink colour in salmon is mostly due to deposition of carotenoid pigment astaxanthin (MacDermid et al., 2012). The astaxanthin cannot be produced by the salmon itself and has to be provided through the feed (Anderson, 2001).

The colour intensity of salmon fillets is often compared with colours on the SalmoFan^{TM} scale which ranges from 21-34 (Figure 7). The normal colour range of farmed salmon that is sold on the Norwegian market ranges on the SalmonFan^{TM} scale within twenty-five and twenty-seven (Alfnes et al., 2006).

Figure 7: SalmoFan ^{TM} Colour Measurement scale (DSM, 2016)

The optical appearance of food is an important quality parameter and the consumers recognize changes in the flesh colour of salmon(Alfnes et al., 2006). Fillets with discoloured areas can be downgraded (Koteng, 1992). Melanin pigmentations in the fillet or blood spots are visible quality issues that represent a problem in the commercial aquaculture (Krasnov et al., 2016). In the Atlantic salmon industry, the occurrence of melanin spots is the major quality issue (Berg et al., 2012).

2.5. Melanin

Melanin belongs to insoluble and stable biochemicals and groups of natural pigments that are defined as complex, multifunctional biopolymers of high molecular weight (Jacobson, 2000). Specific cells called melanocytes produce the melanin which is responsible for the dark discoloration of the fish (Hearing & Tsukamoto, 1991).

Dendritic cells of the immune system synthesize melanin. The specific cells are called melanocytes and they are originated from the ectoderm of the skin. Melanosomes are organelles that act as a control mechanism for the balance of melanization.

There are three different forms of melanin; neuromelanin, pheomelanin and eumelanin which is the most common type in bony fish (Agius & Roberts, 2003). Eumelanin has a black or brown colour and it is influenced by the melanocyte stimulating hormone (Hearing & Tsukamoto, 1991).

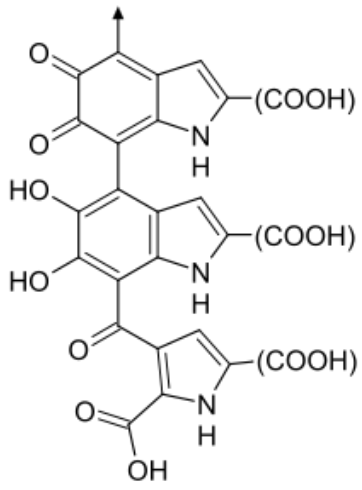


Figure 8: Structure of eumelanin (Ito and Wakamatsu, 2008)

In food, melanin is supplemented not only on the basis of good health effects, but also as additive for the colour and the flavour. Since the 14th century in Venice melanin is included in dishes to enhance the taste of their products like pasta-neri. The black pigmentation of food like Truffles and Caviar is based on melanin. It is known that melanin in herbal food brings benefits for health and contributes to a good digestion (NPS, 2013).

2.5.1. Melanin in fish

The occurrence of melanin in fish fillets represents serious quality damages (Koteng, 1992) compared to other food products where melanin is seen as a healthy food supplement (NPS, 2013). Mathiassen et al. (2007) define melanin spots as dark spots that reduce the quality grade of a salmon fillet.

In the muscle tissues, visceral organs and peritoneum of ectothermic vertebrates dark pigmentation appears frequently (Mackintosh, 2001). Compared to the other sections of a fillet, dark spots more often occur in the front part of the fillet (Mathiassen et al., 2007, Mørkøre, 2012). With a diameter from 1 up to 3cm melanin also occurs on the surface of the fillet (Mørkøre, 2008). A standard method has been developed for scoring the melanisation of salmon fillets, taking into account three different locations of the salmon fillet; the front ventral is called Buk1, the second one is named Buk2 and the dorsal part is termed Rygg, (Figure 9). Most of the melanisations in salmon fillets appear in Buk1 followed by Buk2 and some fillets showed dark pigmentation in the dorsal part (Mørkøre et al., 2015).

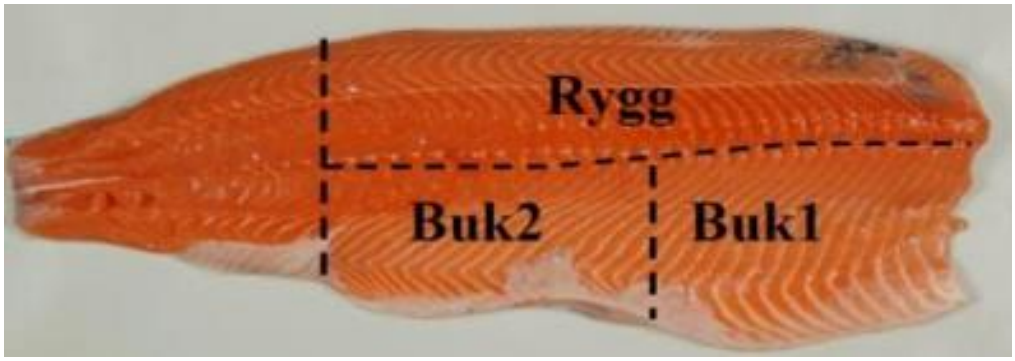


Figure 9: Classification of the different fillet sections (Mørkøre et al., 2015)

The Melanin spots can occur in different intensities. Dark discoloration is often a result of melanin deposition. Some dark spots contain scar tissue or blood pigments and the spots look

more red than black. Other spots are a combination of blood pigments, melanin and scar tissue, therefore it can sometimes be difficult to distinguish (FAO, 2013). **Error! Reference source not found.** illustrates the different sizes and explains the different descriptions of melanin.

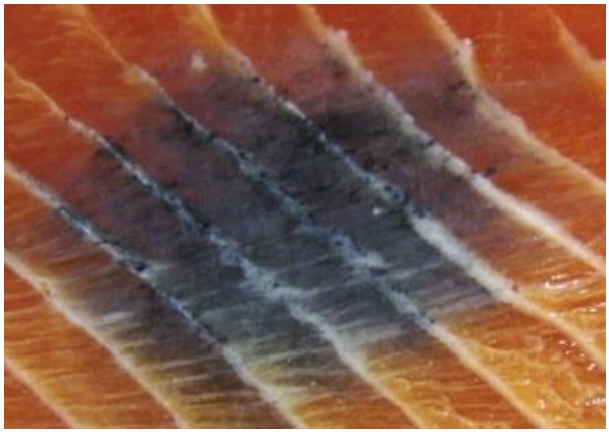


Figure 10: Melanin spot in Atlantic salmon fillet (Larsen et al., 2012)

With the growing presence of melanin spots and the fact that they do not disappear in the further processing, they are a big visual quality problem (Mørkøre, 2008).
Even though melanin is a natural ingredient in a lot of food without any side effects like toxic or allergic reactions known (FAO, 2013), customers do not accept discoloured fillet flesh as a quality product (Mathiassen et al., 2007).

The problem with dark hyper pigmentation does not only appear in Norwegian farmed salmon but it has also been recorded in Canada, the US, Chile, the UK and Ireland. The quality damages due to melanin spots in salmon fillets cost the Norwegian fish farming industry approximately one hundred million euros per year (Risbråthe, 2015).

The processing companies have to treat the fillet with dark melanin spots further, means they have to remove the affected parts of the fillet. The removing of the affected tissues reduces the fillet weight and the product has to be downgraded, as it cannot be sold as a whole fillet. This extra labour is a serious cost factor and the product price on the market is decreased (Mathiassen et al., 2007).

In 2006 it was reported that some processing plants had loss of salmon fillets up to 30% due to the occurrence of melanin spots and the removal of them (Thorsen, 2006). Approximately

8-20% of the fillets contained melanin spots in 2007 and 4% of those fillets had to be rejected (Mathiassen et al., 2007). In 2013 a frequency of approximately 12% of weak greyish spots with a diameter smaller than 3cm and about 2% of dark melanin spots with a diameter bigger than 3cm were observed (FAO, 2013). The national average in Norway was 19% in 2015. The presence of dark spots in salmon fillets varies geographically and between production plants within the same geographic area (Mørkøre et al., 2016). The highest observation of melanin spots in salmon fillets occurred geographically in the central area of Norway with 24% and the lowest observation with 13% took place in the north of Norway. Despite as one could believe, the temperature difference in those regions is not a reason for the different results (Mørkøre, 2012, Mørkøre et al., 2015).

Usually melanin spots in fillets were seen as a result of vaccination (Koppang et al., 2005). This relation was for example suggested after a slaughterhouse in Norway detected different significances in the occurrence of melanin in vaccinated and not vaccinated salmon (Jafelice, 2014). Vaccine is often based on non-metabolic mineral oils that can enhance inflammatory reactions because of the long inert hydrocarbons with the immunity against biochemical responses (Spickler & Roth, 2003). Another study discovered that there are no significant differences regarding the appearance of melanin spots in unvaccinated and in vaccinated fish (Berg et al., 2012). According to Larsen et al. (2012) the production of the dark pigmentation in the muscle is a consequence of an inflammatory reaction response form of the immune system and the pigment system in Atlantic salmon.
This implies that there are several different reasons for dark melanin pigmentations in salmon (Mørkøre et al., 2015) and that the vaccination itself is not the main reason for the dark discolouration; however the inflammatory reaction at the injection spot can be seen as one cause (Mutoloki et al., 2004).

Pancreas disease (PD) is an infectious virus that is triggered by the salmonid alpha virus (SAV) (Jansen et al., 2010) and causes high economic losses in Norway (Aunsmo et al., 2010). It is assumed that (PD) influences a higher occurrence of dark pigmentation in fillets and as a result responsible for downgrading of salmon fillets (Bjerkeng, 2004).

Recently Bjørgen et al. (2015) explored that dark pigmented tissues contain the virus Piscine orthoreovirus (PRV). The actual process of how PRV is establishing in the muscle tissue is not clear. The PRV virus is related to the heart skeletal muscle inflammation (HSMI), that

often occurs in Norwegian salmon farms. Indirectly environmental factors can influence the occurence of melanin spots as well, because the factors can influence the outbreak of the Piscine orthoreovirus (Bjørgen et al., 2015).

Feed ingredients play an important role regarding the health of the salmon and the production and appearance of melanin (Mørkøre et al., 2015). Wang (2016) reported a significant reduction of the size and a 14% decreased presence of melanin spots due to adding antioxidants (Vitamin C, E and selenium) as supplement in the feed.

2.6. Disease

Disease problems are among the main challenges in aquaculture and cause high economic losses (Meyer, 1991). Farmed salmon is susceptible to various kinds of diseases such as parasites, viral and bacterial diseases (Lillehaug & Skrudland, 2007). Viral diseases constitute one of the largest problems in the farming of Atlantic salmon. The infectious virus PD triggered by the salmonid alphavirus (SAV) and the also infectious disease heart skeletal muscle inflammation (HSMI), which is initiated by the piscine orthoreovirus (PRV) are widespread diseases in the aquaculture farming industry. The two triggering viruses SAV and PRV often occur in the same locations and co-infections can be recognized. Further investigations about this cross linkage are not done yet (Lund et al., 2016).

2.6.1. PD

In 1989 the pancreas disease was recorded for the first time in salmon aquaculture farms in Norway (Poppe et al., 1989). After the disease was first seen in just one area of Norway in 2003 there was an epidemic increase of the PD outbreaks in other regions. Nowadays the disease is responsible for the loss of a high amount of salmon in the farming industry (Lillehaug & Skrudland, 2007). The subtype 2 and 3 of salmonid alphavirus (SAV2 &SAV 3) causes the PD in Norway (McLoughlin and Graham, 2007).

Normally the PD outbreak appears half a year or longer after the salmonids were moved to saltwater. The standard symptoms of the virus have chronic properties. First the developing virus causes necrosis in the pancreas, afterwards PD harms the heart muscles and it also damages the skeletal muscle. Even changes in the spleen and the kidney have been seen in Norwegian salmon after a pathological examination (Lillehaug & Skrudland, 2007).

Figure 11: Fish of the same population after an PD outbreak ((Lillehaug & Skrudland, 2007) (Photo: T.T.Poppe))

Low mortality and a loss of appetite are characteristics of PD. The mortality rate can be up to 40% in an infected batch (Ruane et al., 2005). As a long term result the virus reduces the growth rate and can cause small and thin fish (Figure 11) and reduced flesh quality due to muscle damages (Lillehaug & Skrudland, 2007). Aunsmo et al. (2010) described that one PD outbreak in a farm with 500.000 smolts and high biological losses can reach an economic loss of 14.4 million NOK.

2.6.2. HSMI

The disease heart and skeletal muscle inflammation (HSMI) was first reported in Atlantic salmon farms in 1999 and since then the outbreaks have increased every year (Kongtorp et al., 2004). So far in Europe HSMI was detected in Scotland and Norway (Ferguson et al., 2005). Compared to 2010 the HSMI outbreak in Norway increased by approximately 20% in 2011, with a total of 162 infected farm sites and most of them seawater cages. Also two juvenile production units that are using seawater in their production were diagnosed with the disease (Biering & Garseth, 2012) .

The main characteristics of HSMI are necrosis of red myocytes, inflammation and serious pancarditis (Bjørgen et al., 2015). The first disease symptoms are visible after 5-9 months after the transfer to the sea sites. Clinical signs are anorexia, abnormal swimming performance and a mortality up to 20% (Garseth et al., 2013). The mortality rate can be increased due to environmental stress (Finstad et al., 2012). Results of autopsies show yellow liver, a pale heart, petechiae in the perivisceral fat and swollen spleen (Kongtorp et al., 2004) (Figure 12).

Figure 12: HSMI infected fish with a visible paler heart than normal ((Lillehaug & Skrudland, 2007) (Photo: T. Taksdal))

There are no methods yet to control HSMI but the development of a vaccine is in process. Due to the widespread of HSMI it became a notifiable disease in Norway and stands on List 3 of the national diseases (Bjørgen et al., 2015).

HSMI is associated with the new reovirus, piscine reovirus (PRV). A relationship between cardiac histopathology and PRV particles as well as a correlation between the severity of the disease and PRV viral loads have been explored (Finstad et al., 2012). Despite these research findings there was also a frequent high presence of the PRV in healthy salmon (Tengs, 2012). This suggests further factors contributing to the development of disease. This implements that further studies on the relation between HSMI and PRV have to be done to confirm previous explorations (Johansen et al., 2015).

3. Material & methods

The research methods of this study are based on a quantitative and qualitative survey methodology. The aim of the survey was to obtain insights about the processing industry experiences regarding fillet quality problems in Atlantic salmon with emphasis on melanin spots and the economic implication of this quality issue.

The material and methods chapter is divided into two parts. The first part is dealing with the material and methods of the survey. The second part is dealing with a case study based on the materials and results of a separate and earlier published study „Effekt av fôr på melaninflekker i laks infisert med både PRV og SAV“ reported by Mørkøre et al. (2016). The second part shows an example of how the results from the survey can be used.

3.1. Survey

A web survey was sent out in October and November 2016 using the online survey software Qualtrics.

The questionnaire was designed to be easy to follow and quick (approximately 5-10min) to complete. Survey setup and question formulation were prepared with own created questions. Literature review did not uncover similar surveys on which this one could be based on. The questionnaire has been written in the English language as this is the world's most important and widely used language in global science (Cenoz & Jessner, 2000). To find representative companies for the survey, online research was done.

The target group were companies that process farmed Atlantic salmon. 240 processing companies in Norway (166), Germany (50) and Poland (24) were asked to participate. The companies received an email with a link to the online based questionnaire. In this first email the companies received information regarding the project and were kindly asked to participate. One reminder email was sent out to the companies. A letter with the online link to the survey was sent in an email to the Bundesverband der deutschen Fischindustrie und des Fischgroßhandels e.V. in Germany who supported the study by sending out the letter in their weekly broadcast to its members, where 50 of the members were fish processing companies. The designed questionnaire can be seen in the appendix.

3.1.1. Questionnaire design and introduction

The survey included 20 questions and was separated in five parts. The questionnaire began with an introduction. The introduction was followed by the parts “Quality”, “Melanin spots”, “Economy” “Company information”. The classification into various thematic sections was not visible to the respondents to avoid interference.

16 of the questions, were closed questions. Only four questions were open ended questions where participants were asked to comment on specific issues. In the following the different parts of the survey are explained in more detail.

Introduction

General information was given to the participants as a short briefing about the questionnaire, why this survey was conducted as well as information about the responsible person for the survey.

3.1.2. Quality

The quality part consisted of two questions about general quality issues in Atlantic salmon fillets and their frequency.

The first question was a drag and drop ranking question about five quality issues: “pale colour”, “melanin spots”, “soft texture”, “gaping” and “blood spots”.

The participants were asked to use the computer mouse to drag the different quality issues into the preferred order. 1 represented the largest problem and 5 was the smallest problem.

The second question was created as a likert scaled matrix table with five statements and six scale points. The participants were asked to share their opinions on how frequently they experienced pale colour, melanin spots, soft texture, gaping and blood spots. The six answer scale points were “never”, “rarely”, “sometimes”, “often”, “always” and “I don’t know”. Just one answer was possible for each quality issue.

3.1.3. Melanin

Four questions were part of this section about the general problem with melanin spots in Atlantic salmon fillets.

This section started with a picture of different sizes of melanin spots and was used to clarify what captions are used for each size of melanin (Figure 13).

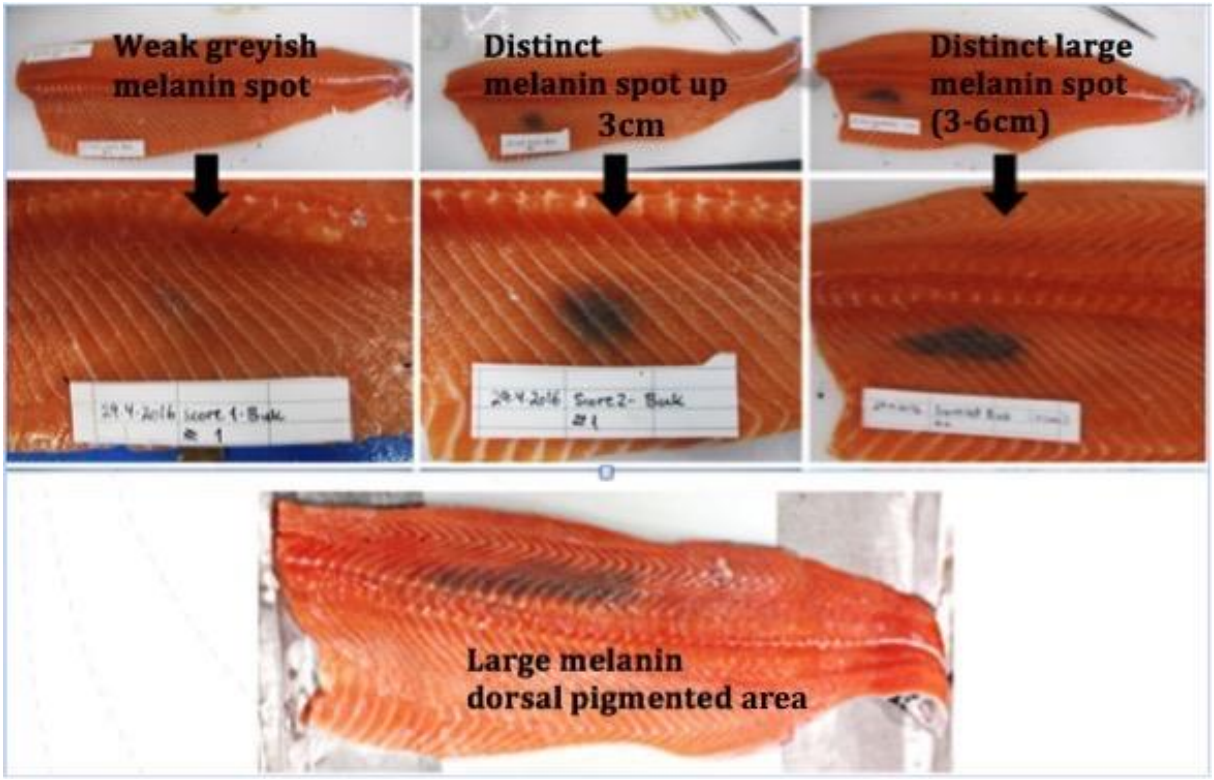


Figure 13: Captions for the different sizes of melanin spots in Atlantic salmon fillets in the survey

- Weak greyish melanin spot
- Distinct melanin spot up to 3cm
- Distinct large melanin spot (3-6cm)
- Large melanin dorsal pigmented

The first question was a likert scale with four statements and six scale points. The participants were asked to rate how frequently they experienced the different sizes of melanin spots in Atlantic salmon fillets. The reply possibilities were “never”, “rarely”, “sometimes”, “often”, “always” and “I don’t know”. The respondents were able to assign only one scale point to each statement.

The second question was designed as a slider question and had only one answer choice. The slider question was a rating question where the participants could drag an interactive slider on a numerical scale (0-100) to rate an item. The participants were asked to give a total percentage of melanin spots in Atlantic salmon fillets in their company by dragging the interactive slider to the preferred number.

The third question was a multiple-choice question with six answer possibilities from which the participants could choose what they believe is the reason for melanin spots in Atlantic salmon fillets.

The response options were:

- Feed
- Harvesting procedure
- Vaccination
- Disease outbreak
- Stress
- Other

The participant had the possibility to choose multiple answers.

The fourth question was a likert scale with four statements and six scale points. The participants were asked to share how their company treats the different sizes of melanin spots. The different scale points were specified as:

- Accepting as normal
- Removing only the pigmented tissue
- Removing whole fillet parts with affected area
- Downgrading the product
- Removing from food chain
- I don’t know

3.1.4. Economy

This part consisted of three questions regarding the perceived economic implication of melanin spots.

This section started with a picture of different sizes of melanin spots and was used to remind the participants what captions are used for each size of melanin spots (see Figure 13).

The first question was designed as a slider question and had four statements that had to be answered separately. The four statements were the different types of treatments for melanin spots. The slider question was a rating question where the participants could drag the interactive sliders on a numerical scale (0-100) to rate the items. The participants were asked to give an approximate percentage of price loss for a product due to the different treatments of melanin spots; 0 illustrated no price loss of a product and 100 characterized a complete price loss of a product.

The second question was designed as a multiple-choice question with six different answer possibilities. Only a single answer was possible. The participants were asked to state to what degree they believe melanin spots have become an economic problem.
The possibilities were:

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree
- I don´t know

The third question was designed as a slider question and had four statements that had to be answered separately. The four statements were the different sizes of melanin spots. The slider question was a rating question where the participants could drag the interactive sliders on a numerical scale (0-100) to rate the items. The participants were asked to give an approximate percentage of economic loss for different sizes of melanin spots in Atlantic salmon. 0 illustrated no economic loss and 100 characterized a loss of the entire fillet.

3.1.5. Company information

This part of the online based survey was created to get information about the companies that participated in the survey.

The section consisted of eight questions. One of the questions was added later and was therefore not visible for all of the participators.

The first question was a multiple-choice question with five answer possibilities. Multiple answers were possible. The participants were asked about the origin of the Atlantic salmon that they were processing.
The answer possibilities were:

- Norway
- Chile
- Canada
- Scotland
- Others

The second question was a multiple-choice question with six answer possibilities. Multiple answers were possible. The participants were asked which types of products they produce.
The answer possibilities were:

- Fresh fillets
- Frozen fillets
- Smoked fillets
- Cutlets
- Ready meals
- Other products

The third question was an open question with a single line to fill out. The participants were asked to write in how many tonnes of Atlantic salmon they were processing per year, approximately.

The fourth question was a multiple-choice question with four answer possibilities. Multiple answers were possible. The participants were asked where they sell their products to.
The answer possibilities were:

- Europe
- Asia
- USA
- Others

The fifth question was a multiple-choice question with four answer possibilities.
Only a single answer was possible. The participants were asked about the size of their company they worked for.
The answer possibilities were:

- 1-10 employees
- 11-50 employees
- 51-100 employees
- Over 100 employees

The sixth question was a multiple-choice question with three answer possibilities.
Only a single answer was possible. The participants were asked in which country the company they worked for was located.
The answer possibilities were:

- Norway
- Poland
- Germany

This question was added in the survey later and therefore not visible for every participant.

The seventh question was an open question with a single line to fill out. The participants were asked to write in their position in the company.

The survey was closed with an open question with a single line to fill out. The participants were asked about the name of the company the participants worked for.

As an extra service of the online survey software Qualtrics, a location data, using the source GeoIP Estimation, was automatically set in every survey.

3.1.6. Statistical evaluation

Most of the results were nominal and ordinal scaled and only a few were metrical scaled. The evaluation of the data was therefore done with descriptive statistics and only some parts with an analytical procedure where standard deviation and standard error was calculated. The evaluation was carried out in Excel 2016.

Descriptive statistics

Presentation of collected nominal and ordinal scaled results of the survey was done by using tables and figures. Description of the data was based on absolute and relative frequency.

Analytical statistics

The analytical procedure allowed to calculate the mean, the minimum, the maximum, the modal value, the standard deviation and standard error of the metric scaled answers.
Frequency tables, average values and variance and standard error were presented in tables and figures. The frequency tables were used to show the percentage distribution of the number of observations. Average values were used to compare the different results.

3.2. Case study

The case study was done to exemplify utilisation of the results of the survey. The case study is based on results in an earlier published report of Mørkøre et al. (2016) where the impact of feed on melanin spots in salmon infected with piscine orthovirus (PRV) and salmonid alpha virus (SAV3) was investigated. Therefore, this part of the material and methods chapter first

presents the most important material and methods and results of the report, and afterwards the assumptions and calculations of the case study.

3.2.1. Earlier published report

Material and Methods

The Atlantic salmon used in the earlier published study from Mørkøre et al. (2016) was farmed in Radoy in Hjeltefjorden, Hordaland, Norway. The location had six cages (120 m circumference). Four of the six cages belonged to Nofima research licences while two belonged to the farming company Blom Fisheries.

At the end of June 2016, the Veterinary Institute (NVI, Oslo) detected fish co-infected with SAV3 and PRV. Histopathological changes indicated a disease outbreak with heart skeletal muscle inflammation (HSMI) and pancreas disease (PD) which was associated with the SAV3 and PRV co-infection.

After the transfer to the sea in September (2 cages) and October (4 cages), the salmon were fed with two different types of feed. The control feed was fed throughout the sea phase or some cages got a test feed for a certain period of time; prior to, during and a period after the disease outbreak. The test feed was a lean, protein rich diet (46.1% protein/ 24.7% fat) compared to the control feed that contained a protein/ fat ratio (36.5%/ 34.5%) commonly used in the commercial feed according to the size of the fish. Three net pens per feed type were used.

The salmon were harvested when the body weight within each net pan was 4kg on average gutted weight. Grading of the harvested and gutted fish was done by external evaluation with the quality grading “superior”, “ordinary”, “production” and “sorted out”. The fish were machine filleted and evaluation of the melanin spots included the registration of the location of the spots by using the position classification (Buk1, Buk2, Rygg) (Figure 9), as well as the size of the spots (score 1= weak greyish spot, score 2= distinct melanin spot up to 3cm, score 4= distinct large melanin spot (3-6cm), score 8= large melanin dorsal pigmented area) (Mørkøre, 2012). Feed effects on melanin spots were processed statistically by using the

computer programs Excel and SAS and doing a T-test and non-parametric test (Kruskal Wallis).

Relevant results for the case study

The results of the report showed that on average 21.2% of the fish in the control group had melanin score 1, 16.3% score 2 and 10% melanin score 4 & 8 (Table 1). For the test group 17.9% had melanin score 1, 12.1 % score 2 and 3.5% had score 4 & 8.

Table 1: Occurrence of the different sizes of melanin spots in % and the associated standard errors after using the different diets (Mørkøre et al., 2016)

	Melanin score 1	Melanin score 2	Melanin score 4 & 8
Control feed	21.2 ± 3.9	16.3 ± 1.3	10.0 ± 4.4
Test feed	17.9 ± 0.8	12.1 ± 1.3	3.5 ± 0.3

The report results showed the average percentage of fish in the different quality classes based on exterior examination of the fish ("superior", "ordinary", "production" and "sorted out") for the two different diet groups and the date of harvesting (Table 2).

Table 2: Percentage for each of the quality classes based on external examination for the different feeding groups and the different harvesting dates (Mørkøre et al., 2016)

Harvesting date	Feed group	Superior	Ordinary	Production	Sorted out
14.01.16	Test	96.4%	1.3%	0.9%	1.3%
11.02.16	Control	83.3%	6.4%	1.6%	8.7%
18.03.16	Test	89.8%	2.8%	2.0%	5.4%
01.04.16	Test	85.9%	3.2%	3.3%	7.6%
28.04.16	Control	79.7%	5.7%	5.9%	8.8%
23.05.16	Control	73.1%	11.9%	7.4%	7.6%
Average test group	Test	90.7%	2.4%	2.1%	4.8%
Average control group	Control	78.7%	8%	4.9%	8.4%

3.2.2. Material and methods case study

Some assumptions have been made based on the results in the report.

Assumptions

- 3 net pens with an equal number of 80000 fish harvested per net pen; i.e. 240000 fish per treatment
- Average gutted weight of fish: 4kg
- Superior and ordinary fish were merged in the group “superior” and the lower quality graded fish was not taken into consideration.
- Test group: 93% “superior” (223200 fish), 892700kg salmon
- Control group: 87% “superior” (208800 fish), 835200kg salmon
- 61.65 NOK per kg for superior salmon (size class 3-4kg, average price in 2016) (NASDAQ, 2015)
- Melanin score 0 are fish without any melanin
- Melanin score 4 and 8 were merged because the report gave no individual information on how many fish had score 8 and how many fish had score 4. For the calculation, the average economic loss for fish with melanin score 4 was used.

Presentation of the results

The results of the case study will be presented in a table with a descriptive text.

Weight of the fish is given in tonnes and the economic values are given in million NOK.

4. Results

The results are presented in two sections.

The first section (4.1) describes the results based on the web based survey that focuses on demographic information, quality issues, melanin and the economic implications of melanin spots in Atlantic salmon fillets. The second section (4.2) presents a case study, where results from the survey on economic implications of melanin spots are implemented. The results are presented in tables and figures and they are annotated with explanatory text.

4.1. Survey results

The web based survey initially focuses on company information, quality issues in general, and thereafter on the results of the questions regarding prevalence of melanin spots and on the perceived economic implication of melanin spots in Atlantic salmon fillets.

4.1.1. Participants and company information

The survey was sent to 240 Atlantic salmon processing companies in Norway, Germany, France and Poland. 52 persons responded, which corresponds with 21.6% of sent surveys. Out of the 52 responses, 31 were considered usable due to the number of questions they answered (≥1 answers=acceptable). Therefore, the survey had a response rate of 12.9% of the 240 sent out surveys.

The number of questions answered varied among the respondents.

Information on the location of the companies was given by 22 participants, whereof 16 were located in Norway (Table 3). Three companies were located in Germany, one in France, one in Scotland and one in Sweden. It is anticipated that most of the companies that did not inform about their location were from Germany.

Table 3: Number of respondents and response rate by the county location

Country	Number of respondents	Response rate
Norway	16	51.6 %
Germany[1]	12	38.7 %
Poland	0	0 %
France	1	3.2 %
Scotland	1	3.2 %
Sweden	1	3.2 %
Total	31	100 %

19 participants answered the question about their profession in the company (
Figure 14). Respondents were merged into groups and divided in different professions:

- Production and slaughter managing
- Quality manager
- Sales and marketing
- Managing director

The most represented professions were managing director (31.5%) and quality managers (31.5%). 26% of the participants worked in the profession of sales and marketing and 11% in the production and slaughter management.

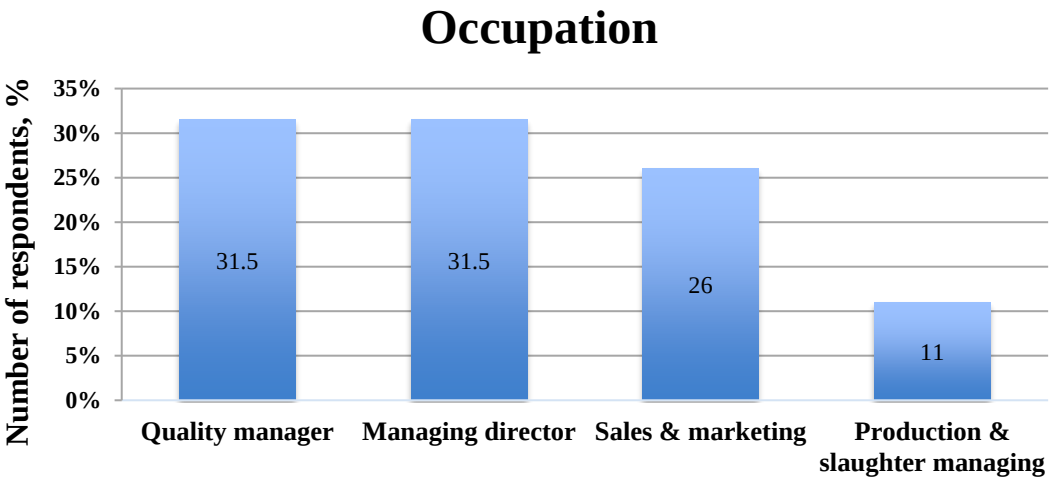


Figure 14: Occupations of the survey participants given as a percentage of the total number of responses (n=19)

[1] It was anticipated that the 9 missing participants from the total number of used survey responses were from Germany.

20 participants responded to the question about the size of their company (Figure 15). Two companies had a size of 1-10 employees, 11 companies had 11-50 employees, one participant answered that the company employed 51-100 employees and six companies had over 100 employees.

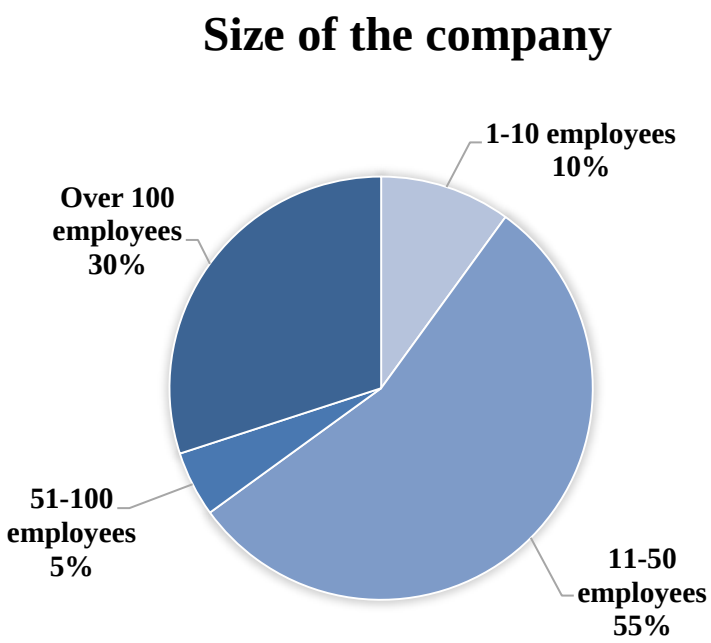


Figure 15: The size of the companies that participated in the survey, given as a percentage of the total number of responses (n=20)

20 participants responded to the question in which countries they sold their products (Figure 16). It was possible for the participants to give more than one answer to the question, therefore a total number of 52 answers were recorded. The results showed that most of the Atlantic salmon products were sold to Europe (n=19) followed by Asia (n=14), other destinations (n=11) and USA (n=12).

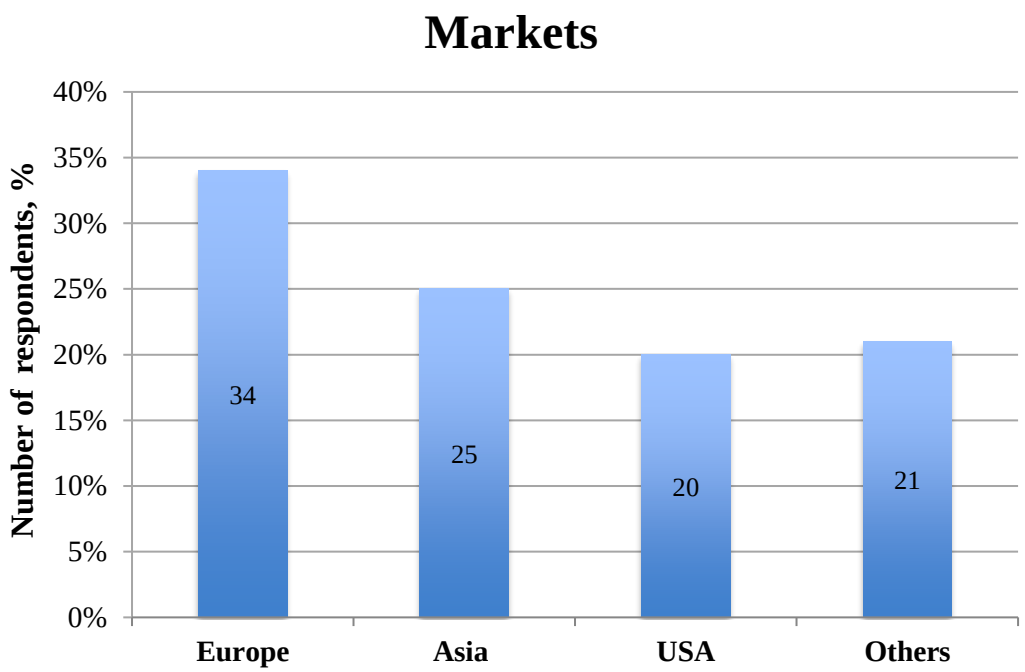


Figure 16: Selling destinations of Atlantic salmon, given as a percentage of the total number of answers (n=52)

A total of 18 participants responded to the question on how many tonnes (t) of Atlantic salmon they were processing per year (Table 4). The average amount was 16685 tonnes (t) per year and the most common volume was 400 tonnes (t). The maximum amount was 110000 tonnes (t) and the minimum was 10 tonnes(t) per year.

Table 4: Amount of Atlantic salmon in tonnes (t) processed per year by the industry that participated in the survey

Processing in tonnes per year	Mean	Maximum	Minimum	Modal value	Total N
Atlantic salmon in tonnes (t)	16685t	110000t	10t	400t	18

20 participants gave information about what kind of salmon products they produced (Figure 17). It was possible for the participants to give more than one answer to the question (n=48). Most of the companies processed to fresh fillets (n=14), frozen fillets (n=11) and smoked fillets (n=10). Eight of the 20 participants processed salmon cutlets and another 15 to other products.

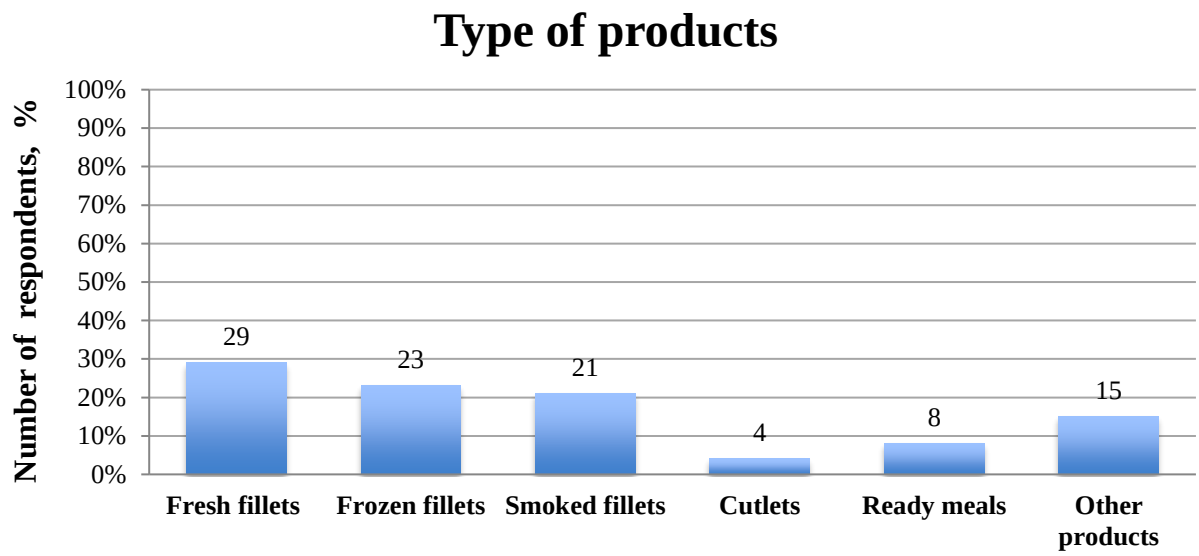


Figure 17: Share different types of salmon products, given as a percentage of the total number of answers (n=48)

20 participants responded to the question about the origin of the processed Atlantic salmon (Figure 18). It was possible for participants to give more than one answer to the question (n=31). From 20 participants that responded, 65% received the Atlantic salmon from Norway, 3% from Chile, 6% from Canada, 13% from Scotland and 13 % from other countries, respectively.

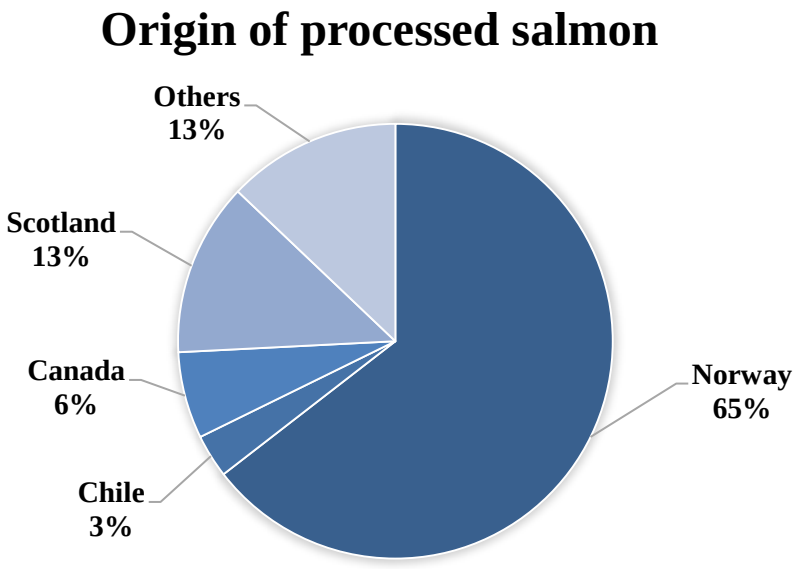


Figure 18: The volume of responses for each origin given as a percentage of the total number of answers (n=31)

4.1.2. General quality issues in the industry

21 participants ranked the different quality issues from 1= very big problem to 5= very small problem (Figure 19). Pale colour (64%) and melanin spots (71%) were regarded as very big/ big problems; hence represented the biggest quality issues in the processing industry. Soft texture and gaping were mainly regarded as a moderate/ small problem (62% for both), although 19-20% of the participants considered problems with soft texture and gaping as big/ very big. Bloodspots were considered as a very small problem by 43% of the respondents, but still 24% of the respondents considered the problem as being big/ very big.

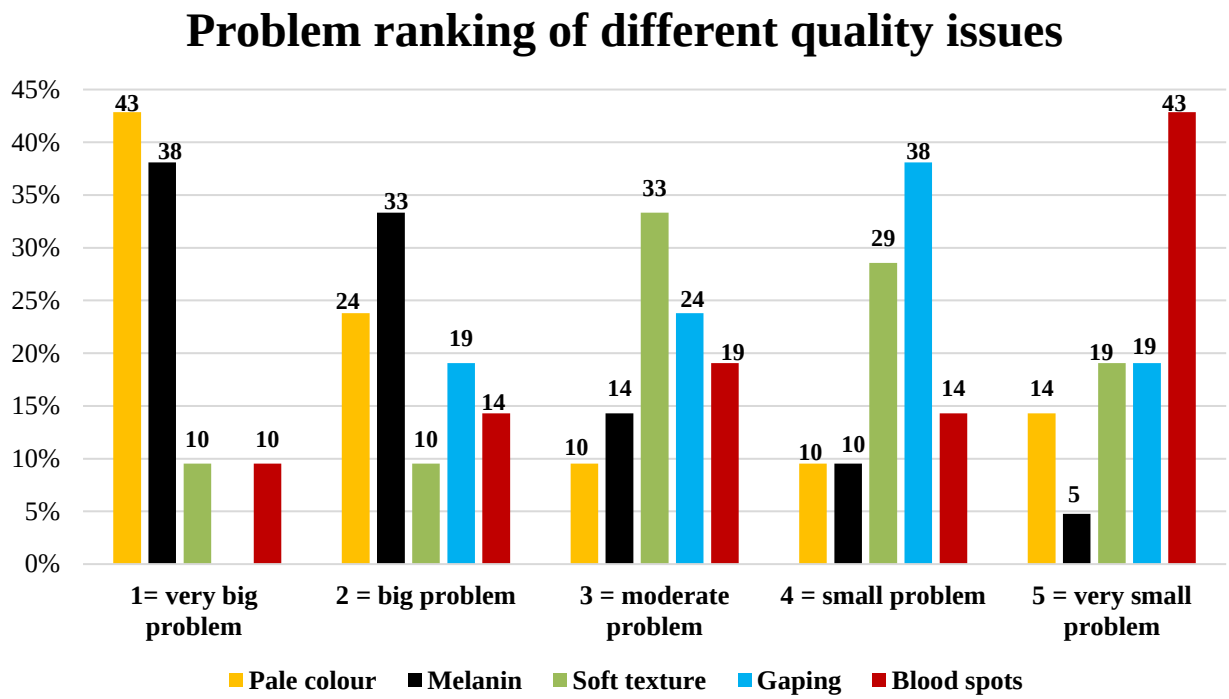


Figure 19: Problem ranking of different quality issues given in percentage of the total number of responses (n=21)

29 participants responded to the question about the occurrence of the different quality issues (

Table 5). The answers varied about how frequent the individual quality problems appeared. Melanin spots was the quality problem with the highest frequency at it was reported to be present "Often/ Always" by 44.8% of the respondents. For the other quality parameters, the ranking was: pale colour (27.6%), blood spots (20.7%), soft texture (17.2%) and gaping (10.4%). All quality problems were reported to occur sometimes (34.5%-51.7%)

None of the participants (0%) chose the answer possibility that melanin never appeared.

Table 5: Frequency of the different quality issues in percentage

Frequency of quality issues	Never	Rarely	Sometimes	Often	Always	I don´t know	Total N
Pale colour	3.5%	31.0%	37.9%	27.6%	0.0%	0.0%	29
Melanin spots	0.0%	17.2%	34.5%	31.0%	13.8%	3.5%	29
Soft texture	6.9%	24.1%	51.7%	17.2%	0.0%	0.0%	29
Gaping	3.5%	41.4%	44.8%	3.5%	6.9%	0.0%	29
Blood spots	10.3%	31.0%	37.9%	13.8%	6.9%	0.0%	29

4.1.3. Melanin issues in the industry

24 participants responded to the question about the frequency of the different sizes of melanin in Atlantic salmon fillets (Figure 20). One participant didn’t know how frequent the different sizes of melanin spots appeared. Weak greyish spots (melanin score 1) and distinct melanin spots up to 3cm (melanin score 2) were always experienced by 21% and 13%, respectively. Melanin score 1 was often observed by 46 % of the participants. Melanin score 2 was observed sometimes by 46% of the participants. More than 50% of the participants observed large melanin dorsal pigmented areas (melanin score 8) rarely. 38% answered that distinct large melanin spots 3-6cm (melanin score 4) appeared rarely. 13% answered that melanin score 4 never occurred. None of the participants answered that weak greyish melanin spots (melanin score 1) was never observed.

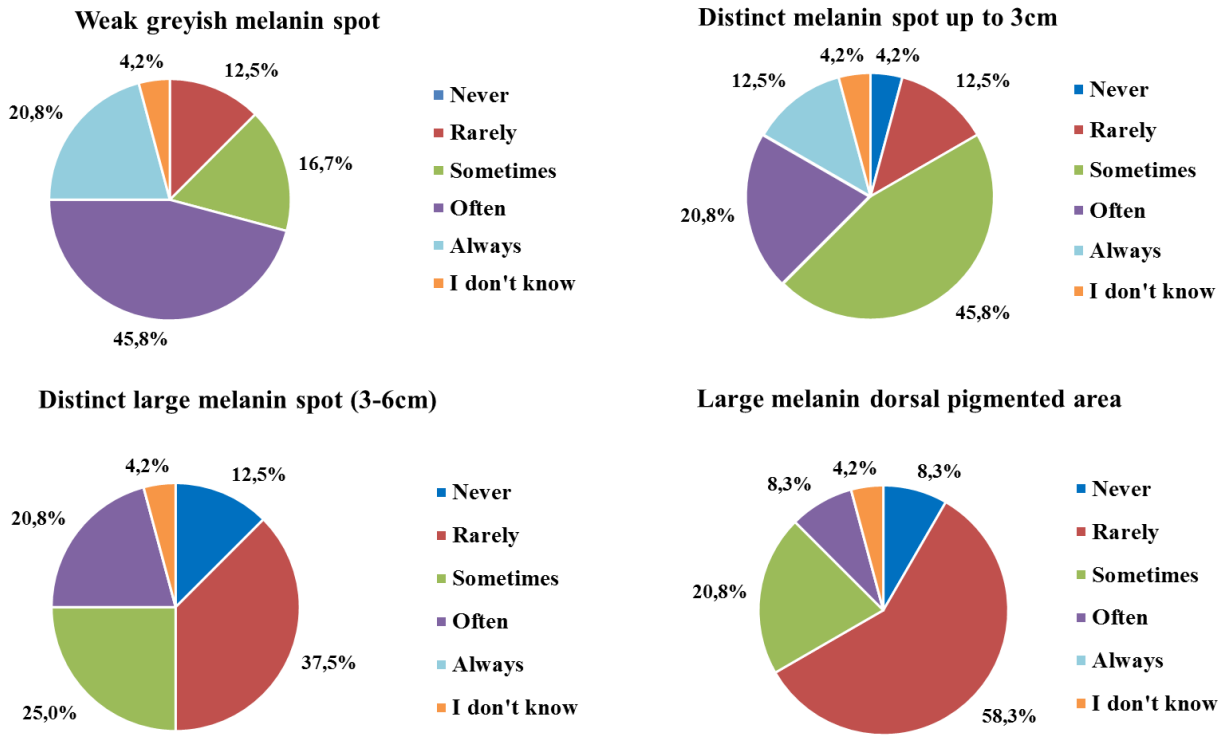


Figure 20: Frequency of melanin spots given as a percentage of the total number of answers (n=24) for the various sizes of melanin.

23 participants responded to the question about the total percentage of salmon with melanin spots (Table 6). On average 16.4% of the salmon processed by the participants were reported to have melanin spots. The observed range was 1-48% and the most common occurrence of melanin spots was 10% (modal value). The results showed a standard deviation of 11.3 and a standard error of 2.4.

Table 6: Melanin spots in Atlantic salmon fillets

Melanin spots in Atlantic salmon	Mean	Minimum	Maximum	Modal value	Std. deviation	Std. error	Total N
Results	16.4%	1%	48%	10	11.3	2.4	23

23 participants responded to the question about their opinion of the main reason for melanin spots (Figure 21). It was possible for the participants to give more than one answer to the question (n=65). Vaccination (23%) and stress (23%) were considered to be the main reasons for melanin spots. 12% answered that feed was a reason for noticeable melanin spots and 11% of the participants expected "other" factors to be the reason for melanin spots.

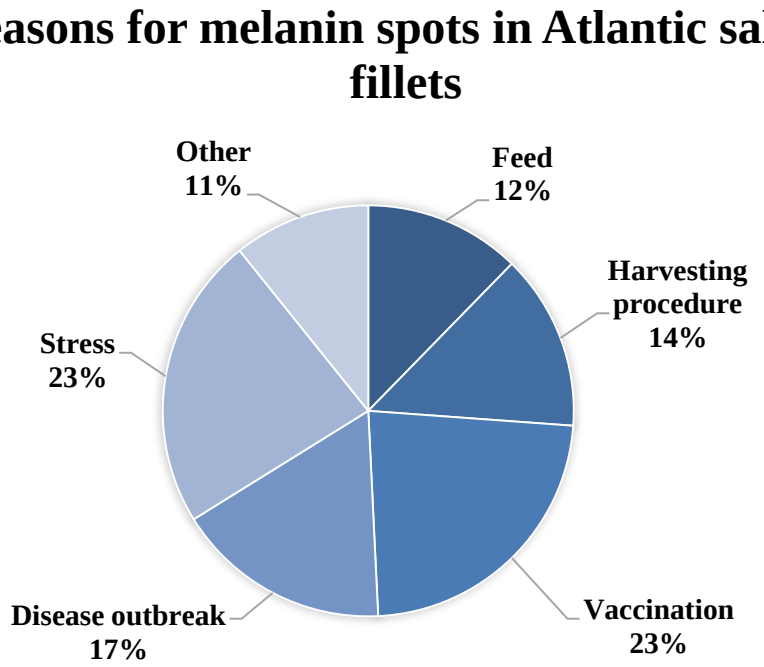


Figure 21: Factors considered to be the main reasons for melanin spots in Atlantic salmon fillets given as percentage of the total number of answers (n=65)

23 participants responded to the question about the treatments of the different sizes of melanin spots (Figure 22). 50% of the weak greyish melanin spots were treated by just removing the pigmented tissue. 25% of the participants accepted this size of melanin as normal. None of the participants indicated that weak greyish melanin spots were removed from the food chain. 8% of the participants accepted distinct melanin spots up to 3cm as normal, whereas 59% removed only the pigmented tissue. 13% removed the whole fillet parts with the affected areas and 8% removed the product from the food chain because of this size of melanin spots.

None of the participants accepted distinct large melanin spots (3-6cm) or large melanin dorsal pigmented areas as normal. The large distinct spots (3-6cm) were mostly treated by downgrading the product (29%) and removing the whole fillet parts with the affected area (25%).

Most of the participants (42%) answered that large melanin dorsal pigmented areas were removed from the food chain, whereas 25% of the participants downgraded the fillets.

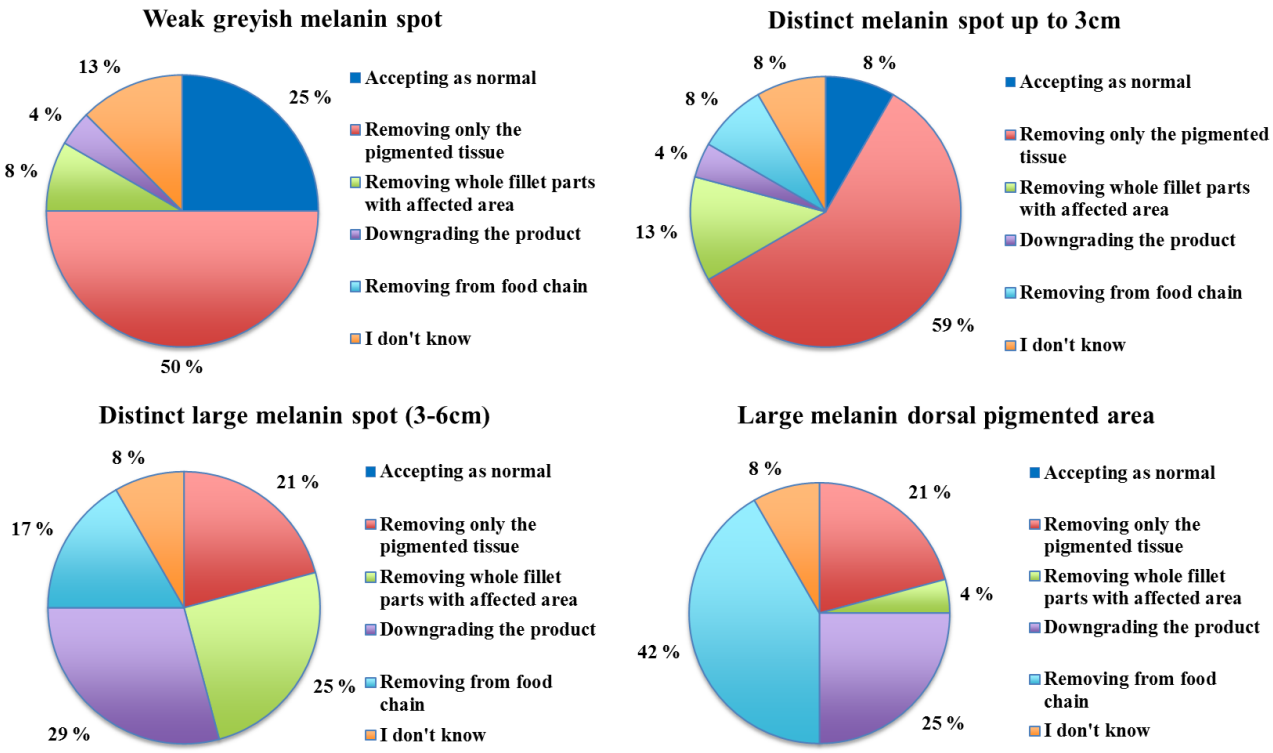


Figure 22: Treatment of the different sizes of melanin spots given as a percentage of the total number of answers for each size of melanin (n=24)

When melanin spots were considered, regardless of the size and intensity of melanisation, 38% of the participants just removed the pigmented tissue (Figure 23). 17% of the participants removed the fillets from the food chain and 16% downgraded the fillets. The occurrence of melanin was accepted as normal by 8% of the participants.

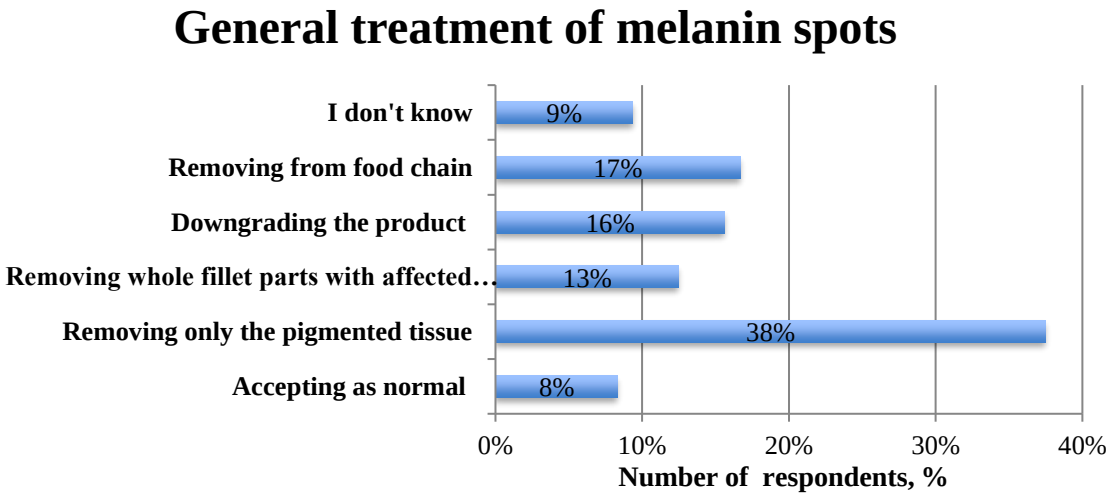


Figure 23: General treatment of melanin spots in Atlantic salmon fillets regardless of the size of the melanin spots. Results are presented in percentage of the total number of answers.

4.1.4. Economic implication of melanin spots

17 participants responded to the question regarding the price loss due to “removing only the pigmented tissue” and another 17 responded to the price loss of “downgrading the product”, (

Table 7). 16 participants responded to the price loss of “removing whole fillet parts with affected area” and 15 to the price loss of removing the product from the food chain. On average the price loss for removing only the pigmented tissue was 9% (range 0-30%). Most of the participants answered that this treatment had a product price loss of 0%. An average price loss of 23% (range 1-50%) was reported for removing whole fillet parts with affected area. The modal value was 30% of product price loss for removing the whole fillet parts with affected area. The mean price loss for downgrading the product was 26% (range 0-71%) and the modal value was 25%. The average product price loss for removing from the food chain was 67% (range 1-100%). The modal value was 100% (

Table 7).

Removing the fillets from the food chain had the highest standard deviation (40.9) and removing only the pigmented tissue the lowest (7.6).

Table 7: Average price loss (%) for the different treatments of melanin spots

Price loss in % for different treatments	Mean	Minimum	Maximum	Modal value	Std. deviation	Std. error	Total N
Removing only pigmented tissue	9%	0%	30%	0%	7.6	1.9	17
Removing whole fillet parts with affected area	23%	1%	50%	30%	15.2	3.8	16
Downgrading the product	26%	0%	71%	25%	21.8	5.3	17
Removing from food chain	67%	1%	100%	100%	40.9	10.6	15

23 participants responded to the question if the occurrence of melanin spots in Atlantic salmon has increased and become a greater economic problem (Figure 24). 35% strongly agreed that melanin became an economic problem and another 22% disagreed with that. 17% agreed and 22% answered that they neither agree nor disagree. The answer possibility strongly disagree was taken out by the presentation of the results because none of the participants answered this option.

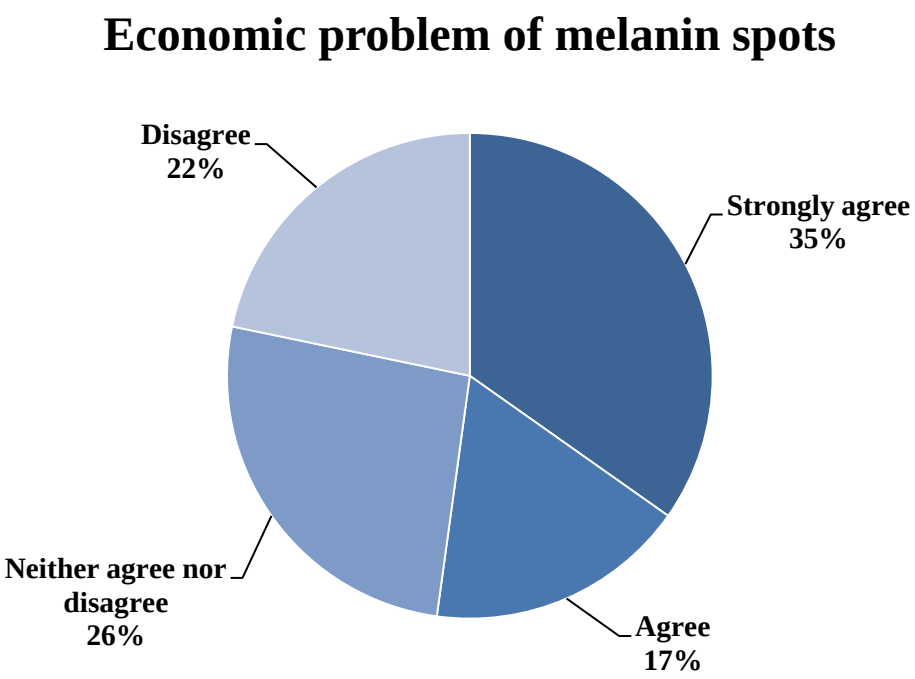


Figure 24: Response to the question if melanin spots in Atlantic salmon fillets has become a bigger economic problem during recent years, given in percentage of the total number of responses (n=23)

17 participants responded to the question about the economic loss due to weak greyish melanin spots (

Table 8). The economic loss due to the other sizes was answered by 18 participants. The average economic loss for weak greyish spots was 8% (range 0-17%). Most of the participants answered that weak greyish spots caused an economic loss of 5%. The mean economic loss for distinct melanin spots up to 3cm was 15% (range 0-50%). The most common answer was 10%. On average large distinct melanin spots (3-6cm) gave an economic loss of 24% (range 1-61%, modal value 29%). The mean economic loss for dorsal pigmented areas was 44% (range 0-100%). Most of the participants answered that this degree of melanized tissue implicated an economic loss of 100%.

Weak greyish spots had the lowest standard deviation with 4.5 and large melanin dorsal pigmented areas the highest with 37.4.

Table 8: Average economic loss (%) for the different sizes of melanin spots

Economic loss of different sizes of melanin in%	Mean	Minimum	Maximum	Modal value	Std. deviation	Std. error	Total N
Weak greyish melanin spot	8%	0%	17%	5%	4.5	1.08	17
Distinct melanin spot up to 3cm	15%	0%	50%	10%	12.1	2.86	18
Distinct large melanin spot (3-6cm)	24%	1%	61%	29%	16.9	3.98	18
Large melanin dorsal pigmented area	44%	0%	100%	100%	37.4	8.82	18

By using the results of the average economic losses for the different sizes of melanin spots (table 8) and the following assumptions: a total production cost of 28.58 NOK (MarineHarvest, 2016), the annual average prices for salmon in 2011 (31.99 NOK/kg) and 2015 (42.09 NOK/kg) (FPI, 2017) and the calculated average price for salmon in the weight class 3-4kg (61.65 NOK/kg) in 2016 (NASDAQ, 2015), Figure 25 illustrates the economic loss due to different raw material prices and the cost efficiency regarding the treatment of the fillets with different melanin sizes.

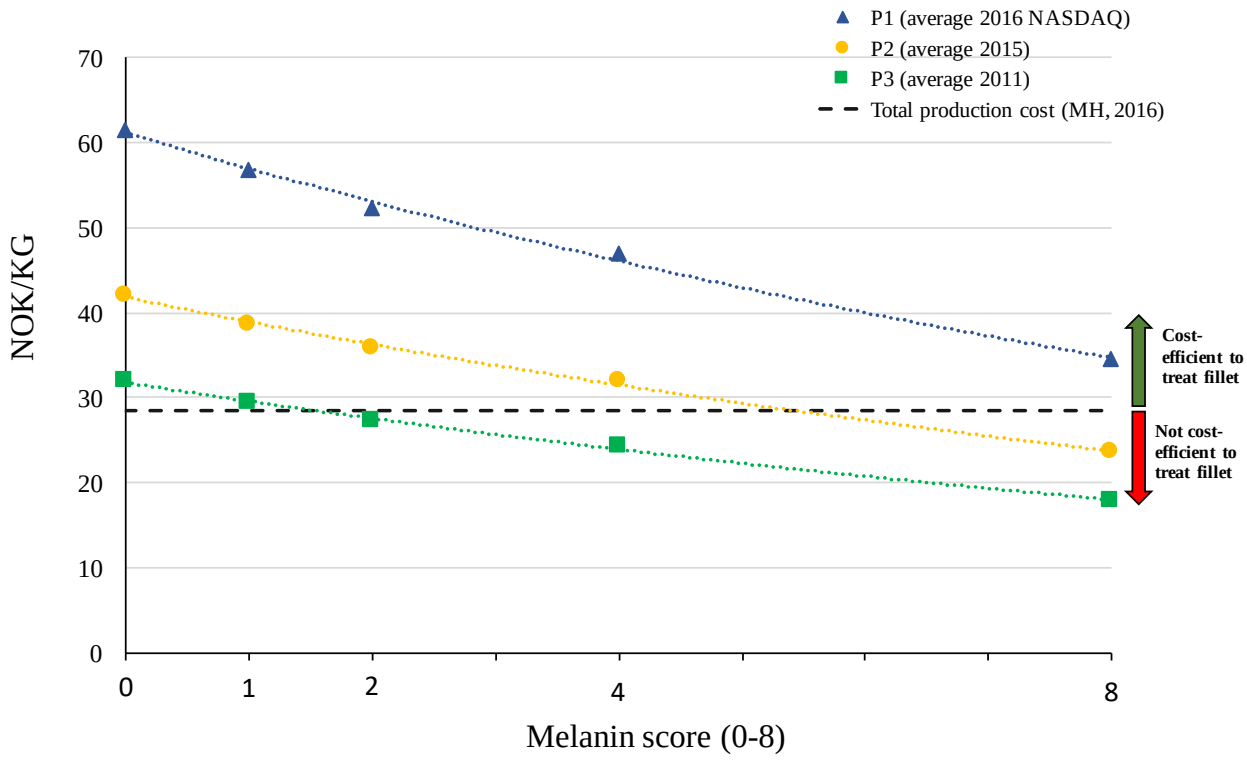


Figure 25: Economic loss for different sizes of melanin spots (score 0-8) relatively to three different raw material prices, at assumed total production costs. The area below the assumed production costs can be considered as fillets that are not economically feasible to treat

4.2. Results of the case study

Test group

A total number of 223200 (93%) of the assumed 240000 fish were considered to be filleted ("superior" or "ordinary") in the test group (Table 9). The total weight of the 223200 fish was 892.7t (223200* 4kg). 159.8 tonnes (t) (17.9%) of the Atlantic salmon had score 1 and 31.2 tonnes (t) (3.5%) of the fish in the test group had score 4 & 8.

The price/kg for fish with melanin score 0 was assumed to be 61.65 NOK (NASDAQ, 2015). Based on the results from the survey, the fillets with score 1, score 2 and score 4 & 8 was 8%, 15% and 24%, respectively. Accordingly, the price per kg for fillets with melanin spots was 56.72 NOK/kg for score 1, 52.40 NOK/kg for score 2 and 46.85 NOK/kg for score 4 & 8.

The calculated economic value of salmon with melanin score 1 was 9.064 million NOK and 1.271 million NOK for score 4 & 8. The total economic value of the fish in the test group was 52.598 million NOK.

The assumed economic value of the optimal and fictitious case that there would only be melanin score 0 was 55.041 million NOK. The calculated economic loss was therefore 2.443 million NOK (4.4 %) due to melanin spots in the salmon of the test group.

Control group

A total number of 208800 (87%) of the assumed 240000 fish were considered to be filleted ("superior" or "ordinary") in the control group (Table 9). The total weight of the fish was 835 tonnes (t) (208800*4kg). 177 tonnes (t) (21.2%) of the Atlantic salmon had score 1 and 83.5 tonnes (t) (10%) of the fish in the control group had score 4 & 8.

The price/kg for the fish with melanin spots was considered to be the same as for the test group. The economic value of the salmon with melanin score 1 was 10.043 million NOK and 3.398 million NOK for score 4 & 8. The total economic value of the fish in the control group was 47.607 million NOK.

The assumed economic value of the optimal and fictitious case that there would only be melanin score 0 was 51.490 million NOK. The calculated economic loss was therefore 3.883 million NOK (7.5 %) due to melanin spots in salmon of the control group.

Benefit of the test diet

Based on the economic loss for the test diet group of 2.443 million NOK (4.4%) and for the control diet of 3.883 million NOK (7.5%), the calculated economic benefit of the test diet is a 3.1% lower economic loss due to the melanin spots; in example 1.440 million NOK. When taking the higher number of fish in the test group that were anticipated to be filleted the economic benefit of the test feed was 4.99 million NOK.

Table 9: Economic values of the test and control groups when occurrence of melanin spots was noticed for fillets with different sizes of melanin spots. The number of fish within each dietary group are based on fish classified as “superior” and “ordinary”

Test group	Average Economic loss	NOK/kg (salmon weight class 3-4kg)	% of melanin test group	Number of fish	Weight of the fish in tonnes (t)	Economic value in million NOK
Melanin score 0	0%	61.65	66.5%	148428	593.7	36.602 NOK
Melanin score 1	8%	56.72	17.9%	39952.8	159.8	9.064 NOK
Melanin score 2	15%	52.40	12.1%	27007.2	108	5.661 NOK
Melanin score 4 & 8	34%	40.69	3.5%	7812	31.2	1.271 NOK
Total				223200	892.7	52.598 NOK
Control group	**Average Economic loss**	**NOK/kg (salmon weight class 3-4kg)**	**% of melanin control group**	**Number of fish**	**Weight of the fish in tonnes (t)**	**Economic value in million NOK**
Melanin score 0	0%	61.65	52.5%	109620	438.4	27.032 NOK
Melanin score 1	8%	56.72	21.2%	44265.6	177	10.043 NOK
Melanin score 2	15%	52.40	16.3%	34034.4	136.1	7.134 NOK
Melanin score 4 & 8	34%	40.69	10%	20880	83.5	3.398 NOK
Total				208800	835	47.607 NOK

5. Discussion

Overall survey

This study was conducted as an analysis of the general problem, the frequency and the economic implication of melanin spots in the processing industry of Atlantic salmon.

Compared to surveys with a good distribution and a well running data collection, the number of respondents in this study was not entirely satisfying. According to the research results of Tse-Hua Shih (2008), the respondents rate of the survey for this study (21.6%) was below their estimated average value of 34% respondents for online based surveys. After removing the non-usable replies the respondents rate was even lowered to 12.9% (31 companies). With this low response rate, the risk may be high that the respondents cannot be seen as fully representative for the processing industry.

Based from the number of participating countries, it was striking that none of the asked companies from Poland participated in the survey. There can be different reasons why the respondents rate was low. The participation in the survey was voluntary and therefore some companies maybe did not see the need to answer. Also, some companies may have not seen the importance of the topic or just had a lack of time to answer the survey.
Salmon is a typical Christmas dish, therefore the quantity of the production of salmon products is rising in that time (Steen and Salvanes, 1999). Those calendar dependent events like Christmas and Easter are also influencing and increasing the price of the salmon (Forsberg and Guttormsen, 2006), hence the companies try to increase their sales in those seasons. The survey was conducted during the hectic and busy working time before the Christmas season. This might be a reason, to the relatively low response rate.
Further explanations for the low response rate can be for example technical problems, perception as a spam mail, the impersonal contact, misunderstanding of the questions or concerns about the privacy and safety sphere (Evans & Mathur, 2005). One reason could also be a language barrier because of the fact that the survey was given in English and the countries, the survey was sent out to, were not having English as their mother-tongue, for example Poland.

There are some advantages and disadvantages of using an online based survey compared to other types of surveys. First advantage of an online survey is the ease of data collection. The

internet connects people all over the world and gives therefore the opportunity to reach a lot of people in a short time (Garton, 1999, Taylor, 1999, Yun & Trumbo, 2000). Secondly the use of online surveys requires lower costs compared to other methods (Bachmann et al., 1996, Couper, 2000, Ilieva et al., 2002, Yun & Trumbo, 2000). Paper surveys include for example the costs of the paper and also for sending them out. Online based surveys are also more inexpensive than the face to face method were you for example have to include costs for visiting the participants. Another advantage is the easy handling and automatic data input that saves the researcher a lot of time compared to other methods (Ilieva et al., 2002). Online surveys are more impersonal and therefore they give the participants the chance to answer honestly without having fears to get judged and also have the opportunity to choose the time for answering the survey compared to face to face interviews. Compared to other questionnaire methods the online based surveys often give the best chances to build complex questions with more than one type of response format.

On the other hand, online surveys have some disadvantages that need to be taken into consideration when the decision of using that type of questionnaire is made. Even though the online survey is expected to gather data easily due to the internet, some people have limited access to the internet. Therefore, this type is only usable for participant groups where it is ensured that they have internet access.
The anonymity of the online survey used in the present study gave the participants a higher chance to answer honestly about sensitive economic data and the participants were not influenced by the opinion of an interviewer. A disadvantage could however be the lack of opportunity to explain ambiguities in person to the participants and therefore misunderstandings can have appeared. Technical challenges can be another disadvantage. In this study, there were some part time technically problems where some of the participants could not see the whole questionnaire and had only access to a limited number of questions. Also, the use of web based surveys brings the risk that some people are not responding because the mail with the link is regarded as a spam mail.

In this case an online survey was chosen because of the time and cost benefits and it was also easier to reach a large number of participants. A disadvantage in this case was on the other hand that the participants were able to skip some questions and therefore each question had a different number of answers.

The results of this survey may contribute with valuable information for the processing industry on the economic implication of melanin spots in Atlantic salmon fillets.

Participants and company information

The demographic distribution of the survey was confined to Europe; i.e. the survey was sent out to three different countries (Norway, Germany and Poland). These countries were on one hand chosen because they all process salmon but on the other hand they were also of interest because of their different main positions on the market. Norway is one of the biggest producer of Atlantic salmon (FAO, 2017), Germany is one of the biggest importers of processed salmon in Europe (MarineHarvest, 2016) and Poland is establishing their important position as a salmon processing country on the European salmon market (Asche & Bjørndal, 2011).

Regarding the different professions of the participants, it was obvious that most of the participants were employed as quality managers and managing directors whereas only a few of the participants worked in the profession of production and slaughter management.
The different professions can explain the varying answers along the whole survey, because every occupation group has different contact with the product and there is also a diverse knowledge of the quality issue melanin spots and the economic implication of it.

Another reason for the widely different answers in the survey can be the fact that the individual companies produced different products. Different processing procedures have different expectations of the quality of the raw material. For some companies, pale colour might be a bigger problem compared to melanin spots, depending on the further process of the salmon. Melanin spots become more intense after smoking process (Mørkøre, 2008), a fact that probably makes the producer of smoked salmon more sensitive to the questions about melanin spots compared to the producers of raw or frozen cutlets.

More than half of the companies in the survey employed 11-50 employees, hence the present results mostly reflect the opinions of medium sized companies in the processing industry.

The main market for the participants in the survey was the European Union, that is considered as the biggest single salmon market in the world (Asche & Bjørndal, 2011). As 51.6% of the participants were companies operating in Norway the significance of the results is reinforced by the fact that that Norway is mainly trading salmon with the European Union (Johnsen &

Nilssen, 2001). The other main markets of Norway are Asia and Russia (MarineHarvest, 2016) which explains the outcome that 25% sold their product to Asia and 21% to other countries. In the literature USA was not mentioned as one of the main markets for Norway and Germany, therefore the nearly equal results to Asia and other countries were a bit unexpected.

In average the participants processed 16685 tonnes (t) of Atlantic salmon per year, this is compared to the modal value of 400 tonnes (t) per year quite high and obviously just a result of the wide range of answers (10t-110000t). The large variation in the answers can be related to the different sizes of the companies. Some companies were big and processed mostly a higher amount of fish compared to the small companies. The lower modal value is reflected and justified by the fact that most of the participants were middle sized companies.

Apart from the processed quantity of Atlantic salmon it was interesting to see that the answers regarding the types of produced products were distributed in a nearly similar frame for fresh fillets, frozen fillets and smoked fillets. In the literature (AIPCE-CEP, 2015), the imported processed products to Europe show differences and illustrate that frozen fillets and fresh fillets had the highest import volume in 2014, (**Error! Reference source not found.**). The reason for the nearly equal quantity of answers about production of fresh fillets, frozen fillets and smoked fillets could be a result of the fact that the participants did not only trade with Europe. Therefore, the companies probably produced a varying quantity of the different salmon products to meet the requirements of the other markets.

The results of the origin of the processed salmon showed that most of the participants ordered their raw material from Norway. This agrees with the literature that most of the Atlantic salmon is farmed in Norway (FAO, 2017). It can also be related to the fact that Europe is the main market for Norway (Johnsen & Nilssen, 2001).

General quality issues in the industry

It is to mention that external quality issues like deformities were not mentioned in the questionnaire due to the fact that this study mainly focused on melanin spots in Atlantic salmon fillets. Quality characteristics of particular importance for the secondary processing were focused and the quality grading in the secondary processing is based on the characteristics of the muscle of the filleted fish (Michie, 2001).

The results of the survey showed pale colour and melanin spots were clearly the biggest problems and blood spots the least problem.
This partly supports the literature for example Berg et al. (2012) stating that melanin spots are the major quality issue in the industry. On the other hand, the results indicate that melanin spots are not the only major quality issue, but rather deviating appearance including both insufficient red/ pink pigmentation and melanin hyper pigmentation.

The results regarding the problem ranking of melanin spots and blood spots were totally different and clearly distinguished from each other, which indicates that the participants had a good knowledge of the differences between melanin spots and blood spots. They were able to differentiate between the two quality issues, even though the literature assumes that blood spots and melanin spots are hard to distinguish from each other (FAO, 2013).

Another reason why blood spots were ranked as a smaller problem than melanin spots can be the different frequent occurrence of the diverse quality issues. 10.3% of the participants never observed blood spots whereas 0% of the participants answered that melanin spots never appeared. In comparison 13.8% of the participants always recorded melanin spots in the raw material whereas just 6.9% answered that blood spots always appeared. Most of the participants observed the different quality issues sometimes, therefore a relation between the frequency and the problem ranking is unlikely.

Melanin issues in the industry

To have a closer look at the quality issue of melanin spots in the industry the participants were asked to share their experiences about the frequency of the different sizes of melanin spots. The participants were unanimous that the weak greyish spots occur most often and that large melanin dorsal pigmented areas are rare. Overall the results showed a trend that the bigger the spots are the less they appear. With regard to the industry that means that most of the companies have to deal with the smaller sized melanin spots.
The frequency of the different sizes of melanin spots can also depend on the origin of the raw material, as the presence of melanin varies geographically (Mørkøre et al., 2016).
If these results are compared to the statements about the economic loss caused by the individual sizes of melanin it can be seen that there is no connection between the frequency of the different sizes of melanin spots and the economic losses caused by the different sizes of melanin spots. For example, melanin weak greyish spots were recorded to appear often at

45.8% of the participants but this size of melanin only causes an average economic loss of 8%. In contrast to that, 58.3% of the participant experienced large melanin dorsal pigmented areas mostly rarely and this size causes an average economic loss of 44%.

Melanin spots regardless of the size, occurred with an average of 16.4%. This outcome lies in the range of the average occurrence of melanin in the year 2007 (8-20%) (Mathiassen et al., 2007) and it is also close to the national average of Norway (19%) in 2015 (Mørkøre et al., 2016). This indicates that the results from this survey are representative and reflecting the frequency of melanin spots recorded previously by the Norwegian industry.

In the point of view of the participants, there seems to be more than one reason for the appearance of melanin spots. As they were asked to choose as many of the optional reasons for melanin spots, none of the options got a really high agreement compared to the other choices. On one hand this reflects quite clearly the theory that there are probably several factors influencing the occurrence of melanin spots (Mørkøre et al., 2015). On the other hand, this can also be seen as an indication that more research on this topic has to be done and the industry should be included to prevent a lack of information. The lack of information is mentioned because 23% of the participants answered that vaccination was the reason for melanin spots in Atlantic salmon, but there are already research results that disprove this theory as Berg (2012) mentioned in his article. Also, the fact that 12% of the participants answered that feed is the reason for melanin in Atlantic salmon fillets leads to the assumption that there is a lack of information exchange between the research and the industry. Feed may indeed affect the size and the occurrence of melanin spots (Wang, 2016), but in the research literature, feed is not considered as a main reason for the general phenomenon of melanin spots in salmon fillets.

Regardless to the reason for this quality deficiency, it is clear that the different sizes of melanin spots have to be treated differentially. Weak greyish melanin spots were mainly removed (cut out the melanized tissue) or even accepted as normal by the participants. Also, the distinct melanin spots up to 3cm were usually removed in contrast to the large spots (3-6cm), where the product was often downgraded or complete fillet parts had to be removed. For the fillets with large dorsal melaninzed areas, the general procedure was no treatment but rather removal from the food chain/ downgrading. It seems that the larger the spots the more the fillets are excluded from the food chain.

Economic implication of melanin

The different treatments result in different price losses for the companies. In fact, the price loss results showed that the more the product had to be handled, the higher the average price loss for the product. This, however, appears to be only partly true as it can be seen when the different modal values of the product price losses for the individual treatments are taken into account. Most of the participants replied that the removal of whole fillet parts with affected surfaces leads to a price loss of 30% compared to a price loss of 25% for downgrading the product. On one hand the downgrading seemed to create more labour and effort than removing whole fillet parts with affected areas. On the other hand, a reason for these different experiences of the participants might be due to different product assortments. It is tempting to believe that sometimes it might be more cost-efficient to downgrade the product instead of removing the affected fillet parts.

The high standard deviations for the individual treatments also show the high variation of the answers which is considered to be related to the different strategies of each company to treat melanin spots.

Even though the answers in the survey varied a significantly, one third of the participants strongly agreed that melanin spots become an economic problem. This suggests that preventing melanin spots is an interesting and important topic for further research. In contrast, one could argue that 22% of the participants disagreed that melanin spots in Atlantic salmon have become an economic problem, while 26% neither agreed nor disagreed that the spots become an economic problem. This disagreement is probably, because the participants had different professions, and hence different knowledge and attitude to the problem with melanin spots. A participant who normally works in the production and slaughtering management has on one hand probably more knowledge of the different frequencies of the individual sizes of melanin than the people from the sales and marketing department. On the other hand, they have maybe less experiences with the economic values and economic losses because of melanin than participants that work as managing directors.

The number of answers to the question on whether melanin spots has become an economic problem was too low within each country to draw any conclusion regarding varying attitudes between countries. The largest number of answers to this question came from Norway and showed that most of the participants strongly agreed or agreed that melanin spots have

become an economic problem. However, the answers varied, which suggests that even within a country the opinions about this quality differ.

A similar trend to the price loss related to the different treatments of melanin spots was seen in the economic loss caused by the different sizes of melanin. The bigger the size of the melanin spot the bigger the economic loss. It is significant that there was a huge difference between the average economic loss for weak greyish spots and the large dorsal pigmented areas. However, the high standard deviation among answers regarding economic loss due to large dorsal pigmented areas reflects that the participants worked in different professions or produced different products.

The minimum of 0% economic loss for large melanin dorsal pigmented areas seems to be unrealistic compared to modal value of 100%. However, the participants who chose this low percentage could argue that they have hardly any problems with large melanin spots due to the fact that they order the salmon from an area in where generally less melanin spots occur.

During the last ten years the salmon prices have fluctuated from 25.76 NOK/kg (2007) to 65.32 NOK/kg (February 2017) (FPI, 2017) and also during the year the price can vary significantly (Forsberg and Guttormsen, 2006). It is anticipated that variations in salmon prices affect the magnitude of the economic loss. The Figure 25 illustrated, that during periods with low market prices of salmon, it will not be profitable to use labour to remove melanized tissues, but rather remove the fillets from the food chain. Raw material prices therefore determine whether it is cost efficient to treat or remove the melanised tissue.

Case study

The case study was done to exemplify the utilisation and the relevance of the economic results obtained in the survey. The results are based only on the economic values for the melanin spots in the salmon fillets and does not represent an overall benefit of the test feed versus the control feed. For a total economic calculation, factors like mortality rate and price for feed are required. In this case study a fixed average price for the fish was assumed (average price for the weight class 3-4kg in 2016, 61.65 NOK/kg (NASDAQ, 2015)) even though it is known that salmon prices are changing over the year (Forsberg and Guttormsen, 2006). The number of fish that was assumed to be processed, based on the exterior examination of the fish, were used. The assumption was done according to the Norwegian

Seafood Export Council (1999) who published that fish of the quality grading “superior” and “ordinary” are normally traded compared to the fish graded as “production” or “sorted out”. These standards are voluntary, but the Norwegian Seafood Export Council (1999) recommended that fish graded as “production” or “sorted out” with visible defects like deformities or wounds should not be traded but sold to companies who have the ability to rectify defects.

Based on the results of the economic loss of melanin spots in the survey, it was possible to calculate the price for the salmon in kg for the different melanin scores. The price for melanin score 4 & 8 (46.85 NOK) compared to the price for melanin score 1 (56.72 NOK) underlines the significantly higher economic loss for fillets with severe- compared with minor melanization.

The lower occurrence of melanin spots in salmon fed the test diet already indicated a benefit of the protein rich diet compared to the control diet. Moreover, melanin score 4 & 8 occurred in 10% of the fish in the control group compared to 3.5% in the test group.
Those results influence the economic value because the higher the score of melanin the lower the price per/kg and the higher the percentage of melanin the higher the economic loss.

The optimal case would be that there are only fish without melanin (score 0). This would imply that each salmon would have the market price of a superior fish. It would result in an optimal economic value of 55.041 million NOK for the test group and 51.490 million NOK for the control group. There are already differences in the optimal economic values of the groups, because of the different number of fish assumed filleted in each group. The control group had 13% less fish after the external quality grading compared to 7% less fish in the test group after exterior examination. A sign that the test feed not only affected the size and amount of melanin, but also the external quality of the fish.

The economic loss due to the melanin spots and the external quality grading in the test group was 2.443 million NOK (4.4%) and 3.883 million NOK (7.5%) for the control group. This illustrates that the reduction of melanin due to the test feed resulted lower economic losses. To put it precisely, the test feed had an advantage of 1.440 million NOK (3.1%) compared to the control feed. Summarized this exemplified the use of the survey results to calculate the

different economic losses for the two diet groups related to the external quality grading and the amount of melanin spots.

6. Conclusion

The current study provided significant information about general quality issues in the Atlantic salmon processing industry, the general problem with melanin spots and the economic implication of melanin spots in salmon fillets. Also, the thesis demonstrated utilisation of the, survey based, collected data in a case study.

It can be summarized as follows:

General conclusions

- Pale colour and melanin spots are the biggest problem and blood spots are the smallest problem
- Melanin spots appear more often than other quality issues
- Melanin spots are observed in 16.4% of farmed salmon fillets
- 52% of the participants agree that melanin spots in Atlantic salmon become an economic problem
- The salmon processing industry consider stress and vaccination as the most common reasons for melanin spots in Atlantic salmon fillets
- Lowest price loss for removing only the pigmented tissue (9%)
- Highest price loss for removing the fillet from the food chain (67%)
- The case study illustrated that the results of the survey can be used in different cases

Melanin

Weak greyish spots

- Occurs most frequent compared to the other sizes of melanin spots 66.6% (always & often)
- Mostly only the pigmented tissue is removed
- Cause an average economic loss of 8 %

Distinct melanin spots up to 3cm

- Occurs in 33.3% of farmed salmon fillets (always & often)
- Mostly only the pigmented tissue is removed
- Cause an average economic loss of 15%

Distinct large melanin spots (3-6cm)

- Occurs in 20.8% of farmed salmon fillets (always & often)
- Mostly the fillets have to be downgraded
- Cause an average economic loss of 24%

Large melanin dorsal pigmented areas

- Occurs in 8.3% of farmed salmon fillets (always & often)
- Mostly removed from the food chain
- Cause an average economic loss of 44%

Future recommendation

Melanin

Further studies should be carried out in order to find the reasons for melanin spots in Atlantic salmon fillets, hence improve the profitability in the salmon farming industry to prevent melanin stains to reduce the economic loss.

Survey

For future studies, it is recommended to get into personal contact with potential participants and to send more than one reminder e-mail to receive a higher rate of respondents.

References

AGIUS, C. & ROBERTS, R. 2003. Melano-macrophage centres and their role in fish pathology. *Journal of Fish Diseases,* 26**,** 499-509.

AIPCE-CEP 2015. Finfish study 2015. Brussels: EU Fish Processors and Traders Association.

ALFNES, F., GUTTORMSEN, A. G., STEINE, G. & & KOLSTAD, K. 2006. Consumers willingness to pay for the color of salmon: a choice experiment with real economic incentives. *American Journal of Agricultural Economics,* 88**,** 1050-1061.

ANDERSON, S. 2001. Salmon color and the consumer. *IIFET 2000 Proceedings.* International institute of fishery and economics trade (IIFET 2000).

ASCHE, F. & BJØRNDAL, T. 2011. *The Economics of Salmon Aquaculture*, Wiley.

ASCHE, F., JAFFRY, S. & HARTMANN, J. 2007. Price transmission and market integration: vertical and horizontal price linkages for salmon. *Applied Economics,* 39**,** 2535-2545.

ASLESEN, H. W. 2009. The innovation system of Norwegian aquacultured salmonids. *Fagerberg et al, Innovation***,** 208-234.

AUNSMO, A., VALLE, P. S., SANDBERG, M., MIDTLYNG, P. J. & BRUHEIM, T. 2010. Stochastic modelling of direct costs of pancreas disease (PD) in Norwegian farmed Atlantic salmon (Salmo salar L.). *Preventive veterinary medicine,* 93**,** 233-241.

BACHMANN, D., ELFRINK, J. & VAZZANA, G. 1996. Tracking the progress of e-mail vs. snail-mail. *Marketing Research,* 8**,** 31-35.

BAHUAUD, D., MØRKØRE, T., ØSTBYE, T.-K., VEISETH-KENT, E., THOMASSEN, M. & OFSTAD, R. 2010. Muscle structure responses and lysosomal cathepsins B and L in farmed Atlantic salmon (Salmo salar L.) pre-and post-rigor fillets exposed to short and long-term crowding stress. *Food Chemistry,* 118**,** 602-615.

BERG, A., YURTSEVA, A., HANSEN, T., LAJUS, D. & FJELLDAL, P. G. 2012. Vaccinated farmed Atlantic salmon are susceptible to spinal and skull deformities. *J Appl Ichtyol,* 28.

BIERING, E. & GARSETH, A. 2012. Heart and skeletal muscle inflammation (HSMI) of farmed Atlantic salmon (Salmo salar L.) and the associated piscine reovirus (PRV). *Copenhagen: International Council for the Exploration of the Sea*.

BJERKENG, B. 2004. Colour deficiencies in cold-smoked Atlantic salmon. *Skretting, Norway*.

BJØRGEN, H., WESSEL, Ø., FJELLDAL, P. G., HANSEN, T., SVEIER, H., SÆBØ, H. R., ENGER, K. B., MONSEN, E., KVELLESTAD, A., RIMSTAD, E. & KOPPANG, E. O. 2015. Piscine orthoreovirus (PRV) in red and melanised foci in white muscle of Atlantic salmon (Salmo salar). *Veterinary Research,* 46**,** 89.

BOSTOCK, J., LANE, A., HOUGH, C. & YAMAMOTO, K. 2016. An assessment of the economic contribution of EU aquaculture production and the influence of policies for its sustainable development. *Aquaculture International,* 24**,** 699-733.

CENOZ, J. & JESSNER, U. 2000. *English in Europe: The acquisition of a third language*, Multilingual Matters.

COPPES-PETRICORENA, Z., ALASALVAR, C., SHAHIDI, F., MIYASHITA, K. & WANASUNDARA, U. 2010. Texture measurements in fish and fish products. *Handbook of seafood quality, safety and health applications***,** 130-138.

COUNCIL, N. S. E. 1999. Quality grading of farmed salmon: standard. Bergen: Industry Standards for Fish.

COUPER, M. P. 2000. Review: Web surveys: A review of issues and approaches. *The Public Opinion Quarterly,* 64**,** 464-494.

EINEN, O., MØRKØRE, T., RØRÅ, A. M. B. & THOMASSEN, M. S. 1999. Feed ration prior to slaughter—a potential tool for managing product quality of Atlantic salmon (Salmo salar). *Aquaculture, 178 (1-2): 149-169.*, 178**,** 149-169.

EINEN, O., WAAGAN, B. & THOMASSEN, M. S. 1998. Starvation prior to slaughter in Atlantic salmon (Salmo salar): I. Effects on weight loss, body shape, slaughter-and fillet-yield, proximate and fatty acid composition. *Aquaculture,* 166**,** 85-104.

ESPE, M., RUOHONEN, K., BJØRNEVIK, M., FRØYLAND, L., NORTVEDT, R. & KIESSLING, A. 2004. Interactions between ice storage time, collagen composition, gaping and textural properties in farmed salmon muscle harvested at different times of the year. *Aquaculture,* 240**,** 489-504.

EVANS, J. R. & MATHUR, A. 2005. The value of online surveys. *Internet research,* 15**,** 195-219.

FAO. 2011. *Fishery and Aquaculture Country Profiles. Norway* [Online]. Rome: FAO Fisheries and Aquaculture Department. Available: http://www.fao.org/fishery/facp/NOR/en [Accessed 19.02.2017].

FAO 2013. *Aquaculture production, 2012. Year book of Fishery Statistics,* Rome, Italy, Food and Agriculture organization of the United Nations.

FAO 2014. The State of World Fisheries and Aquaculture, Opportunities and challenges. Rome

FAO. 2016a. *Aquaculture topics and activities. Aquaculture* [Online]. Rome: FAO Fisheries and Aquaculture Department. Available: http://www.fao.org/fishery/culturedspecies/Salmo_salar/en [Accessed 21.02.2017].

FAO 2016b. The State of World Fisheries and Aquaculture, Contributing to food security and nutrition for all Rome.

FAO. 2017. *Statistical Query Results; Aquaculture: Quantity (t)* [Online]. Food and Agriculture Organization of the United Nations. Available: http://www.fao.org/figis/servlet/SQServlet?file=/work/FIGIS/prod/webapps/figis/temp/hqp_2684813657893775795.xml&outtype=html [Accessed 21.02.2017].

FEAP 2016a. Annual Report 2016. Federation of European Aquaculture Producers.

FEAP 2016b. European aquaculture production report 2007–2015 Federation of European Aquaculture Producers.

FERGUSON, H., KONGTORP, R., TAKSDAL, T., GRAHAM, D. & FALK, K. 2005. An outbreak of disease resembling heart and skeletal muscle inflammation in Scottish farmed salmon, Salmo salar L., with observations on myocardial regeneration. *Journal of fish diseases,* 28**,** 119-123.

FINSTAD, Ø. W., FALK, K., LØVOLL, M., EVENSEN, Ø. & RIMSTAD, E. 2012. Immunohistochemical detection of piscine reovirus (PRV) in hearts of Atlantic salmon coincide with the course of heart and skeletal muscle inflammation (HSMI). *Vet Res,* 43.

FIZ. 2016. *Markt; Daten und Fakten* [Online]. Fisch-Informationszentrum e. V. Available: http://www.fischinfo.de/index.php/markt/datenfakten/4855-structurdata-2016 [Accessed 06.11 2016].

FORSBERG, O. I. & GUTTORMSEN, A. G. 2006. THE VALUE OF INFORMATION IN SALMON FARMING. HARVESTING THE RIGHT FISH AT THE RIGHT TIME. *Aquaculture Economics & Management,* 10**,** 183-200.

FPI. 2017. *Price history – weekly, monthly and annual average* [Online]. Fish Pool Index™ (FPI). Available: http://fishpool.eu/price-information/spot-prices/history/ [Accessed 21.02.2017].

FREWER, L. & VAN TRIJP, H. 2006. *Understanding Consumers of Food Products*, Elsevier Science.

GARSETH, Å., FRITSVOLD, C., OPHEIM, M., SKJERVE, E. & BIERING, E. 2013. Piscine reovirus (PRV) in wild Atlantic salmon, Salmo salar L., and sea-trout, Salmo trutta L., in Norway. *Journal of fish diseases,* 36**,** 483-493.

GARTON, L. 1999. Doing Internet Research: Critical Issues and Methods for Examining the Net. *In:* HAYTHORNTHWAITE, C. (ed.). Thousand Oaks, California: SAGE Publications, Inc.

GROSS, M. R. 1998. One species with two biologies: Atlantic salmon (Salmo salar) in the wild and in aquaculture. *Canadian Journal of Fisheries and Aquatic Sciences,* 55**,** 131-144.

HAARD, N. F. 1992. Control of chemical composition and food quality attributes of cultured fish. *Food Research International,* 25**,** 289-307.

HAGEN, Ø., SOLBERG, C., SIRNES, E. & JOHNSTON, I. A. 2007. Biochemical and structural factors contributing to seasonal variation in the texture of farmed Atlantic halibut (Hippoglossus hippoglossus L.) flesh. *Journal of agricultural and food chemistry,* 55**,** 5803-5808.

HEARING, V. J. & TSUKAMOTO, K. 1991. Enzymatic control of pigmentation in mammals. *The FASEB Journal,* 5**,** 2902-2909.

HYLDIG, G. & NIELSEN, D. 2001. A review of sensory and instrumental methods used to evaluate the texture of fish muscle. *Journal of texture studies,* 32**,** 219-242.

ILIEVA, J., BARON, S. & HEALEY, N. M. 2002. Online surveys in marketing research: Pros and cons. *International Journal of Market Research,* 44**,** 361.

ITO, S. & WAKAMATSU, K. 2008. Chemistry of mixed melanogenesis—pivotal roles of dopaquinone. *Photochemistry and photobiology,* 84**,** 582-592.

JACOBSON, E. S. 2000. Pathogenic roles for fungal melanins. *Clinical Microbiology Reviews,* 13**,** 708-717.

JAFELICE, M. P. 2014. *Effects of vaccination and dietary treatment on development and melanin deposition of Atlantic salmon (Salmo salar L.).* Master 60 credits, Norges miljø- og biovitenskapelige universitet (NMBU).

JANSEN, M., TAKSDAL, T., WASMUTH, M., GJERSET, B., BRUN, E., OLSEN, A., BRECK, O. & SANDBERG, M. 2010. Salmonid alphavirus (SAV) and pancreas disease (PD) in Atlantic salmon, Salmo salar L., in freshwater and seawater sites in Norway from 2006 to 2008. *Journal of fish diseases,* 33**,** 391-402.

JOHANSEN, L.-H., THIM, H. L., JØRGENSEN, S. M., AFANASYEV, S., STRANDSKOG, G., TAKSDAL, T., FREMMERLID, K., MCLOUGHLIN, M., JØRGENSEN, J. B. &

KRASNOV, A. 2015. Comparison of transcriptomic responses to pancreas disease (PD) and heart and skeletal muscle inflammation (HSMI) in heart of Atlantic salmon (Salmo salar L). *Fish & shellfish immunology,* 46**,** 612-623.

JOHNSEN, O. & NILSSEN, F. 2001. The Future for Salmon in Germany Norwegian Institute of Fisheries and Aquaculture Research

JOHNSTON, I. A., MANTHRI, S., BICKERDIKE, R., DINGWALL, A., LUIJKX, R., CAMPBELL, P., NICKELL, D. & ALDERSON, R. 2004. Growth performance, muscle structure and flesh quality in out-of-season Atlantic salmon (Salmo salar) smolts reared under two different photoperiod regimes. *Aquaculture,* 237**,** 281-300.

KIESSLING, A., ESPE, M., RUOHONEN, K. & MØRKØRE, T. 2004. Texture, gaping and colour of fresh and frozen Atlantic salmon flesh as affected by pre-slaughter iso-eugenol or CO 2 anaesthesia. *Aquaculture,* 236**,** 645-657.

KIESSLING, A., RUOHONEN, K., BJØRNEVIK, M., 2006. Muscle fibre growth and quality in fish. 137-146.

KLINKHARDT, M. 2005. *Lachse: Die Erfolgsgeschichte des Zuchtlachses* Hamburg, Fachpresse-Verlag.

KLINKHARDT, M. 2010. *Aquakultur Jahrbuch 2010/2011,* Hamburg, Deutschland Fachpresse-Verlag Michael Steinert.

KNAPP, G., ROHEIM, C. A. & ANDERSON, J. L. 2007. The Great Salmon Run: Competition Between Wild and Farmed Salmon. Washington D.C.: World Wildlife Fund.

KONGTORP, R. T., TAKSDAL, T. & LYNGØY, A. 2004. Pathology of heart and skeletal muscle inflammation (HSMI) in farmed Atlantic salmon Salmo salar. *Dis Aquat Organ,* 59.

KOPPANG, E., HAUGARVOLL, E., HORDVIK, I., AUNE, L. & POPPE, T. 2005. Vaccine-associated granulomatous inflammation and melanin accumulation in Atlantic salmon, Salmo salar L., white muscle. *Journal of Fish Diseases,* 28**,** 13-22.

KOTENG, A. 1992. *Markedsundersùkelse norsk laks (Market investigation of Norwegian salmon),* Prosjekt god fisk.

KRASNOV, A., MOGHADAM, H., LARSSON, T., AFANASYEV, S. & MØRKØRE, T. 2016. Gene expression profiling in melanised sites of Atlantic salmon fillets. *Fish & Shellfish Immunology,* 55**,** 56-63.

LARSEN, H. A. S., AUSTBØ, L., MØRKØRE, T., THORSEN, J., HORDVIK, I., FISCHER, U., JIRILLO, E., RIMSTAD, E. & KOPPANG, E. O. 2012. Pigment-producing

granulomatous myopathy in Atlantic salmon: A novel inflammatory response. *Fish & Shellfish Immunology,* 33**,** 277-285.

LAVÉTY, J. 1980. *Gaping in farmed salmon and trout,* Ministry of Agriculture, Fisheries and Food.

LERFALL, J., LARSSON, T., BIRKELAND, S., TAKSDAL, T., DALGAARD, P., AFANASYEV, S., BJERKE, M. T. & MØRKØRE, T. 2012. Effect of pancreas disease (PD) on quality attributes of raw and smoked fillets of Atlantic salmon (Salmo salar L.). *Aquaculture,* 324**,** 209-217.

LILLEHAUG, A. & SKRUDLAND, A. 2007. New Diseases–Phenomena Developing into Problems. *From Cage to Consumption.* Oslo, Norway: The Research Council of Norway.

LIU, D., ZENG, X.-A. & SUN, D.-W. 2013. NIR spectroscopy and imaging techniques for evaluation of fish quality—a review. *Applied Spectroscopy Reviews,* 48**,** 609-628.

LUND, M., RØSÆG, M. V., KRASNOV, A., TIMMERHAUS, G., NYMAN, I. B., ASPEHAUG, V., RIMSTAD, E. & DAHLE, M. K. 2016. Experimental Piscine orthoreovirus infection mediates protection against pancreas disease in Atlantic salmon (Salmo salar). *Veterinary Research,* 47**,** 107.

MACDERMID, J. C., VINCENT, J. I., GAN, B. S. & GREWAL, R. 2012. A blinded placebo-controlled randomized trial on the use of astaxanthin as an adjunct to splinting in the treatment of carpal tunnel syndrome. *Hand,* 7**,** 1-9.

MACKINTOSH, J. A. 2001. The antimicrobial properties of melanocytes, melanosomes and melanin and the evolution of black skin. *Journal of Theoretical Biology,* 211**,** 101-113.

MARINEHARVEST 2016. Salmon Farming Industry Handbook 2016.

MATHIASSEN, J. R., MISIMI, E. & SKAVHAUG, A. A simple computer vision method for automatic detection of melanin spots in Atlantic salmon fillets. Machine Vision and Image Processing Conference, 2007. IMVIP 2007. International, 2007. IEEE, 192-200.

MCLOUGHLIN, M. F. & GRAHAM, D. A. 2007. Alphavirus infections in salmonids--a review. *J Fish Dis,* 30.

MERKIN, G. V., STIEN, L. H., PITTMAN, K. & NORTVEDT, R. 2014. The effect of stunning methods and season on muscle texture hardness in Atlantic Salmon (Salmo salar L.). *Journal of food science,* 79**,** E1137-E1141.

MEYER, F. P. 1991. Aquaculture disease and health management. *Journal of animal science,* 69**,** 4201-4208.

MICHIE, I. 2001. Causes of Downgrading in the Salmon Farming Industry. *In:* KESTIN, S. C. W., P. D. (ed.) *Farmed Fish Quality.* Oxford, UK: Fishing News Books, Blackwell Science Ltd.

MØRKØRE, T. 2008. Tekstur i oppdrettslaks. *Kunnskapsstatus og forhold som bidrar til fastere filet. Nofima, rapportnr,* 32**,** 2008.

MØRKØRE, T. 2012. Filet av oppdrettslaks: Kvalitetsavvik og årsakssammenhenger. *Nofima rapport*.

MØRKØRE, T., DESSEN, J.-E., LARSSONT., GUERRERO R. J. & RØRVIKG K-A. 2016. Effekt av fôr på melaninflekker i laks infisert med både PRV og SAV.

MØRKØRE, T., LARSSON, T., KVELLESTAD, A. S., KOPPANG, E. O., ÅSLI, M., KRASNOV, A., DESSEN, J.-E., MORENO, H. M., VALEN, E., GANNESTAD, K. H., GJERDE, B., TAKSDAL, T., BÆVERFJORD, G., MENG, Y., HEIA, K., WOLD, J. P., BORDERIAS, A. J., MOGHADAM, H., ROMARHEIM, O. H., RØRVIKA, K.-A., NOFIMA, NORGES MILJØ- OG BIOVITENSKAPELIGE UNIVERSITET, CSIS SPANIA & VETERINÆRINSTITUTTET 2015. Mørke flekker i laksefilet, Kunnskapsstatus og tiltak for å begrense omfanget.

MØRKØRE, T. & RØRVIK, K.-A. 2001. Seasonal variations in growth, feed utilisation and product quality of farmed Atlantic salmon (Salmo salar) transferred to seawater as 0+smolts or 1+smolts. *Aquaculture,* 199**,** 145 - 157.

MØRKØRE, T., TAHIROVIC, V. & EINEN, O. 2008. Impact of starvation and handling stress on rigor development and quality of Atlantic salmon (Salmon salar L). *Aquaculture,* 277**,** 231-238.

MØRKØRE, T., VALLET, JL, CARDINAL, M, GOMEZ-GUILLEN, MC, MONTERO, P, TORRISSEN, OJ, NORTVEDT, R, SIGURGISLADOTTIR, S, THOMASSEN, MS 2001. Fat content and fillet shape of Atlantic salmon: relevance for processing yield and quality of raw and smoked products. *Journal of food science,* 66**,** 1348-1354.

MUTOLOKI, S., ALEXANDERSEN, S. & EVENSEN, Ø. 2004. Sequential study of antigen persistence and concomitant inflammatory reactions relative to side-effects and growth of Atlantic salmon (Salmo salar L.) following intraperitoneal injection with oil-adjuvanted vaccines. *Fish & Shellfish Immunology,* 16**,** 633-644.

NASDAQ. 2015.

NASDAQ Salmon Index [Online]. The NASDAQ OMX Group, Inc. Available: https://salmonprice.nasdaqomxtrader.com/public/report?0 [Accessed 21.02.2017].

NAYLOR, R. L., GOLDBURG, R. J., MOONEY, H., BEVERIDGE, M., CLAY, J., FOLKE, C., KAUTSKY, N., LUBCHENCO, J., PRIMAVERA, J. & WILLIAMS, M. 1998. Nature's Subsidies to Shrimp and Salmon Farming. *Science,* 282**,** 883-884.

NEUDECKER, T., HEINRICH, J., LOBITZ, R., BRANDMÄHL, M., DR. KARL, H. & DR. KELLER, M. 2009. *Fisch und Fischerzeugnisse*, aid infodienst Verbraucherschutz, Ernährung, Landwirtschaft e.V.

NICKELL, D. C. & SPRINGATE, J. R. C. 2001. Pigmentation of farmed salmonids. *In:* KESTIN, S. C., WARRISS, P.D. (ed.) *Fish Farmed Quality.* Oxford, UK: Fishing News Book, Blackwell Science Ltd.

NPS. 2013. *Melanin in Food* [Online]. Natural Protection Solutions Inc. Available: http://www.npsmelanin.com/melanin-in-food.html [Accessed 21.02.2017].

NSC 2014. Seafood study 2014. Insight and outlook: How the Germans eat fish Hamburg.

OFSTAD, R., EGELANDSDAL, B., KIDMAN, S., MYKLEBUST, R., OLSEN, R. L. & HERMANSSON, A. M. 1996. Liquid Loss as Effected by Post mortem Ultrastructural Changes in Fish Muscle: Cod (Gadus morhuaL) and Salmon (Salmo salar). *Journal of the Science of Food and Agriculture,* 71**,** 301-312.

POPPE, T., RIMSTAD, E. & HYLLSETH, B. 1989. Pancreas disease in Atlantic salmon (Salmo salar) postsmolts infected with infectious pancreatic necrosis virus (IPNV). *Bulletin of the European Association of Fish Pathologists,* 9**,** 83-85.

RISBRÅTHE, M. 2015. Riddle of dark spots in salmon solved. Ås, Norway: NMBU, (Norwegian University of Life Sciences).

ROBB, D. 2001b. Measurement of Fish Flesh Colour. *In:* KESTIN, S. C. W., P. D. (ed.) *Farmed Fish Quality.* Cornwall: Fishing News Book.

RØRÅ, A. M. B., MØRKØRE, T. & EINEN, O. 2001. Primary processing (Evisceration and filleting). *In:* KESTIN, S. C. W., P. D. (ed.) *Farmed Fish Quality.* Oxford, UK: Fishing News Book, Blackwell Science Ltd.

RUANE, N., RODGER, H., GRAHAM, D., FOYLE, L., NORRIS, A., RATCLIFF, J., MURPHY, K., MITCHELL, S., STAPLES, C. & JEWHURST, H. 2005. Research on pancreas disease in Irish farmed salmon 2004/2005–current and future initiatives.

SHAW, S. & MUIR, J. 1987. *Salmon: Economics and Marketing,* Croom Helm.

SKONBERG, D., HARDY, R., BARROWS, F. & DONG, F. 1998. Color and flavor analyses of fillets from farm-raised rainbow trout (Oncorhynchus mykiss) fed low-phosphorus feeds containing corn or wheat gluten. *Aquaculture,* 166**,** 269-277.

SMITH, M. D., ROHEIM, C. A., CROWDER, L. B., HALPERN, B. S., TURNIPSEED, M., ANDERSON, J. L., ASCHE, F., BOURILLÓN, L., GUTTORMSEN, A. G. & KHAN, A. 2010. Sustainability and global seafood. *Science,* 327**,** 784-786.

SPICKLER, A. R. & ROTH, J. A. 2003. Adjuvants in veterinary vaccines: modes of action and adverse effects. *Journal of Veterinary Internal Medicine,* 17**,** 273-281.

STEAD, S. M. & LAIRD, L. 2001. *The Handbook of Salmon Farming,* London, Springer.

STEEN, F. & SALVANES, K. G. 1999. Testing for market power using a dynamic oligopoly model. *International Journal of Industrial Organization,* 17**,** 147-177.

TAYLOR, H. 1999. Does Internet research work? *International journal of market research,* 42**,** 51.

TENGS, T. 2012. Quantification of piscine reovirus (PRV) at different stages of Atlantic salmon Salmo salar production. *Diseases of aquatic organisms,* 99.

THOMASSEN, M., GUDDING, R., NORBERG, B. & JØRGENSEN, L. 2007. *Aquaculture Research: From Cage to Consumption*, RESEARCH COUNCIL OF NORWAY.

THORSEN, J. 2006. *Isolation, characterization and expression studies of tyrosinase gene family in Atlantic salmon.* PhD thesis, Norges Veterinærhøgskole.

TSE-HUA SHIH, X. F. 2008. Comparing Response Rates from Web and Mail Surveys: A Meta-Analysis. *Field Methods,* 20**,** 249-271.

VENUGOPAL, V. 2005. *Seafood processing: adding value through quick freezing, retortable packaging and cook-chilling,* CRC press.

VERSPOOR, E., STRADMEYER, L. & NIELSEN, J. L. 2008. *The Atlantic Salmon: Genetics, Conservation and Management,* Wiley.

WANG, W. 2016. *The effect of dietary antioxidants on hyperpigmented fillet spots of Atlantic salmon (Salmo salar L.).* Norwegian University of Life Sciences, Ås.

YUN, G. W. & TRUMBO, C. W. 2000. Comparative Response to a Survey Executed by Post, E-mail, & Web Form. *Journal of Computer-Mediated Communication,* 6**,** 0-0.

Appendix

Survey

Quality issues in Atlantic salmon fillets

Q1 This questionnaire is a part of a master thesis at the University in Ås (NMBU), Norway.The aim of the questionnaire is to study the perceived quality issues of Atlantic salmon. The questionnaire will take approximately 5 minutes. Your help is much appreciated and if you have got any question regarding the questionnaire or what it will be used for, do not hesitate to contact Franziska Färber. Email: franziskafaerber@googlemail.com Tlf: +491758590988 Thank you for your participation in advance.

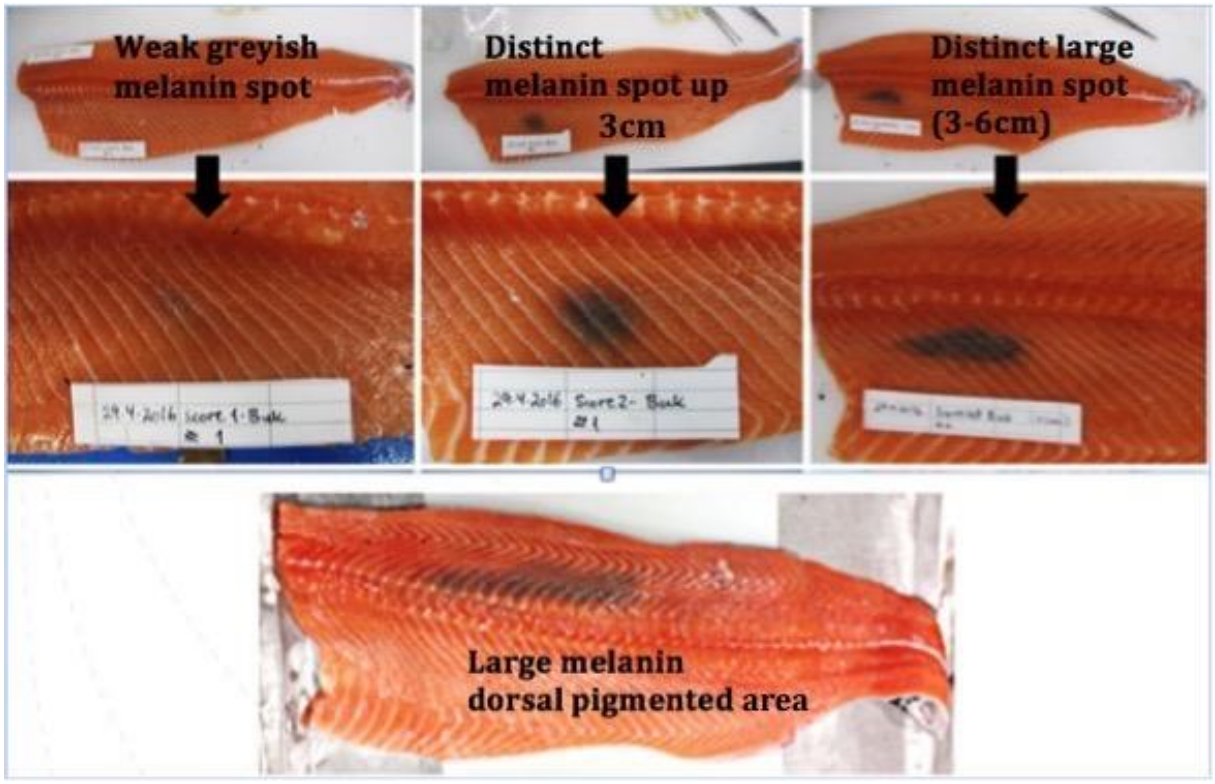
Q2 How would you rank the following quality issues of Atlantic salmon fillets?1 is the largest problem and 5 is the smallest problem. Use the mouse to drag the different quality issues in your preferred order.

_____ Pale colour (1)
_____ Melanin spots (2)
_____ Soft texture (3)
_____ Gaping (4)
_____ Blood spots (5)

Q3 How frequently are you experiencing the following quality issues in Atlantic salmon fillets?

	never (1)	rarely (2)	sometimes (3)	often (4)	always (5)	I don't know (6)
Pale colour (1)	❍	❍	❍	❍	❍	❍
Melanin spots (2)	❍	❍	❍	❍	❍	❍
Soft texture (3)	❍	❍	❍	❍	❍	❍
Gaping (4)	❍	❍	❍	❍	❍	❍
Blood spots (5)	❍	❍	❍	❍	❍	❍

Q4 The following images show the different sizes of melanin spots in Atlantic salmon fillets.



Q5 How frequently are you experiencing the different sizes of melanin spots in Atlantic salmon fillets?

	never (1)	rarely (2)	sometimes (3)	often (4)	always (5)	I don't know (6)
Weak greyish melanin spot (1)	❍	❍	❍	❍	❍	❍
Distinct melanin spot up to 3cm (2)	❍	❍	❍	❍	❍	❍
Distinct large melanin spot (3-6cm) (3)	❍	❍	❍	❍	❍	❍
Large melanin dorsal pigmented area (4)	❍	❍	❍	❍	❍	❍

Q6 Please give a total percentage of melanin spots in Atlantic salmon fillets in your company.

_____ Melanin spots in Atlantic salmon fillets (1)

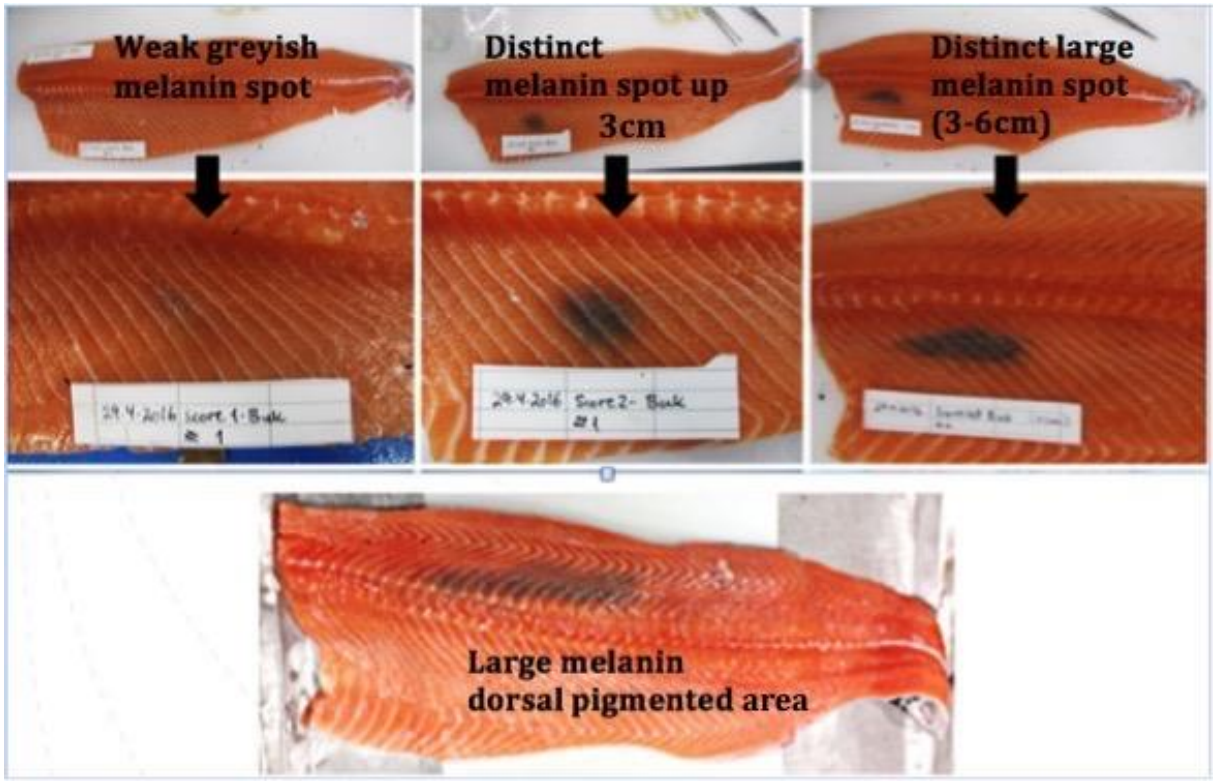
Q7 What do you think the reason is for melanin spots in Atlantic salmon fillets? Multiple answers are possible.

- ❑ Feed (1)
- ❑ Harvesting procedure (2)
- ❑ Vaccination (3)
- ❑ Disease outbreak (4)
- ❑ Stress (5)
- ❑ Other (6)

Q8 How do you treat the different sizes of melanin spots in Atlantic salmon fillets?

	accepting as normal (1)	removing only the pigmented tissue (2)	removing whole fillet parts with affected area (3)	downgrading the product (4)	removing from food chain (5)	I don't know (6)
Weak greyish melanin spot (1)	❍	❍	❍	❍	❍	❍
Distinct melanin spot up to 3cm (2)	❍	❍	❍	❍	❍	❍
Distinct large melanin spot (3-6cm) (3)	❍	❍	❍	❍	❍	❍
Large melanin dorsal pigmented area (4)	❍	❍	❍	❍	❍	❍

Q9 The following images show the different sizes of melanin spots in Atlantic salmon fillets.



Q10 Please give an approximate percentage of how much price loss you have on the product with the different treatments compared to a salmon without any quality issues? (0% is no price loss of the product and 100% complete price loss of the product)

_____ Removing only the pigmented tissue (1)
_____ Removing whole fillet parts with affected area (2)
_____ Downgrading the product (3)
_____ Removing from food chain (4)

Q11 In your opinion, have melanin spots become a big economic problem?

- ❍ Strongly disagree (1)
- ❍ Disagree (2)
- ❍ Neither agree nor disagree (3)
- ❍ Agree (4)
- ❍ Strongly agree (5)
- ❍ I don't know (6)

Q12 Please give an approximate percentage of economic loss for the different sizes of melanin spots in Atlantic salmon fillets? (0% is no economic loss and 100% means that the entire fillet is lost)

_____ Weak greyish melanin spot (1)
_____ Distinct melanin spot up to 3cm (2)
_____ Distinct large melanin spot (3-6cm) (3)
_____ Large melanin dorsal pigmented area (4)

Q13 In which country is the Atlantic salmon that you are processing farmed? Multiple answers are possible.

- ❑ Norway (1)
- ❑ Chile (2)
- ❑ Canada (3)
- ❑ Scotland (4)
- ❑ Others (5)

Q14 Which types of products are you producing?Multiple answers are possible.

- ❑ Fresh fillets (1)
- ❑ Frozen fillets (2)
- ❑ Smoked fillets (3)
- ❑ Cutlets (4)
- ❑ Ready meals (5)
- ❑ Other products (6)

Q15 How many tonnes of Atlantic salmon are you approximately processing per year?

Q16 Where do you sell your products to? Multiple answers are possible.

- ❑ Europe (1)
- ❑ Asia (2)
- ❑ USA (3)
- ❑ Others (4)

Q17 What is the size of your company?

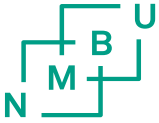
- ❍ 1-10 employees (1)
- ❍ 11-50 employees (2)
- ❍ 51-100 employees (3)
- ❍ Over 100 employees (4)

Q18 In which country is your company located?

- ❍ Norway (1)
- ❍ Poland (2)
- ❍ Germany (3)

Q19 What is your position in the company?

Q20 What is the name of the company you are working for? (Optional)



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