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Commentary

SEAFOOD FROM NORWAY – FOOD SAFETY

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Abstract. Since Norway is a major supplier of seafood worldwide, monitoring the food safety of Norwegian fish products is a priority. This commentary gives a brief overview of the food safety of seafood from Norwegian waters. Several preventative measures during harvest/catch, processing and distribution have been established and are implemented regularly. Furthermore, comprehensive monitoring programmes to detect and quantify undesirable substances, such as heavy metals and polychlorinated biphenyls (PCBs), in Norwegian seafood are carried out. Substances with health benefits, such as omega-3 fatty acids, are also analysed. In general, evidence shows the level of undesirable substances in seafood from Norway to be low. In fact, in the majority of samples analysed, levels of undesirable substances were reported to be below the maximum limit set by the European Union (EU). This leads to the conclusion that consumption of seafood originating from Norway involves a low risk of negative health effects and that consumers can have confidence in the products they purchase.

Keywords: seafood, food safety, Norway, Norwegian practice

1 Introduction

The fisheries and aquaculture industry is one of Norway's most important industries with respect to value and volume. In fact, Norway is the world's second largest exporter of seafood and the European Union (EU) is its most important market (Ministry of Trade, Industry and Fisheries, Norway (MTIF), 2016). About 90% of Norwegian seafood is exported to more than 140 countries worldwide, representing a consumption of approximately 31 million meals daily. In 2015, Norway exported 5.21 billion euros worth of Atlantic salmon and trout, making the aquaculture industry one of the foremost export industries of the country (Norwegian Seafood Council, 2016). This industry represents a vital settlement along the long Norwegian coastline. Among the farmed species, salmon and trout are the key species, but others such as Atlantic cod, Atlantic halibut and Arctic charr are also farmed (Le Francois, Jobling, Carter & Blier, 2010; Sæther, Siikavuopio & Jobling, 2016). In 2015, the weight of Atlantic cod, Atlantic halibut and Arctic charr was 205,935, 15,145 and 52,919 tonnes respectively (Statistics Norway, 2016). From time to time, food safety issues related to seafood are in focus. This can be a result of consumers' experience of seafood meals, or thorough analyses of seafood products. However, such a focus can also be a result of conflicts between countries. In 2011, three Norwegian producers of Atlantic salmon were banned from the Russian market on accusations of the pathogen *Listeria monocytogenes* (*L. monocytogenes*) being present in their products. This was followed up by additional sampling of the salmon by authorities from both countries, resulting in cancellation of the ban (Norwegian Food Safety Authority (NFSA), 2011).

Regardless of the reasons for questioning food safety, buyers of seafood must have confidence in the products they purchase and consume. In Norway, organisations dedicated to seafood safety have created a meticulous surveillance programme that also considers the feed ingredients used in farming. This programme includes both wild caught and farmed fish. The role of such organisations with respect to food safety will be described in this commentary.

Risks associated with the consumption of seafood include the ingestion of microbes (i.e. pathogens), toxins (i.e. algal toxins) and chemical contaminants (i.e. lead, mercury, cadmium or polychlorinated biphenyls (PCBs)). However, consumption of seafood also represents health benefits with respect to nutritional value, with the nutrients best known being omega-3 fatty acids, vitamin D and minerals (i.e. iodide and selenium). The beneficial effects of omega-3 fatty acids on cardiac organs have been extensively studied and they continue to show promising effects in the prevention of cardiovascular disease (Soumia, Sandeep & Jubbin, 2013). The benefits associated with omega-3 are enjoyed through consumption of fatty fish species like Atlantic salmon, trout and herring. It is important to emphasise that most of the risks and benefits described here are not limited to seafood only, but are more prominent in seafood compared to other food products. The aim of this paper is to give a brief presentation of food safety aspects of seafood originating from Norway.

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2 Controlling Food Safety in Norway

The NFSA is Norway's official national supervision and monitoring body for food safety, health and welfare of fish. It implements measures with respect to food safety on behalf of Norway's MTIF. MTIF is the secretariat to the Minister of Fisheries that exercises its administrative authority through adoption and implementation of legislation and regulations. Norway's National Institute of Nutrition and Seafood Research (NIFES) controls seafood with respect to undesirable substances such as veterinary drugs and environmental toxins. Beneficial substances such as omega-3 fatty acids and vitamin D are also analysed by the NIFES. The results of all analyses are available in published reports and internet sites (e.g. www.NIFES.no). The NIFES controls seafood safety on behalf of the NFSA.

In addition to these organisations, the Norwegian Scientific Committee for Food Safety (VKM) carries out independent risk assessments for the NFSA. Topics addressed include environmental risk assessments of genetically modified organisms (GMOs), foreign species and micro-organisms. Incidences of foodborne illnesses are reported to the Norwegian Institute of Public Health (NIPH) on a regular basis. Results are available on the NIPH's homepages (www.MSIS.no). In the EU, the Rapid Alert System for Food and Feed (RASFF) enables information about food safety to be shared among its members, namely EU-28 national food safety authorities, Commission and the European Food Safety Authority (EFSA), including the food safety authorities of Liechtenstein, Iceland, Switzerland and Norway. In the case of food safety issues, information exchanged through this system can lead to recall of products from the market.

3 Wild Fish

Baseline studies of relevant contaminants in wild fish are carried out on a regular basis. Wild fish includes mackerel, Norwegian spring-spawning herring, North Sea herring, Greenland halibut, Atlantic cod and saithe. Based on the results obtained, a follow-up plan is drawn up for each species to ensure that any changes in levels of undesirable substances are discovered. The sampling plan is adjusted according to previous results, volume and position of harvesting. In the case of saithe, analyses of undesirable substances are carried out for fish harvested in the North Sea, the Norwegian Sea and the Barents Sea. Table 1 shows the levels of arsenic, mercury, cadmium and lead, in muscle and liver respectively, for saithe from the North Sea as reported by Nilsen et al. (2013). Fillets of saithe were found to have low levels of undesirable substances, while the level of cadmium in the liver was above the maximum level specified by current EU legislation (Commission Regulation (EC) No. 1881/2006). As seen in Table 1, there are no maximum levels established by the EU for arsenic in seafood. Saithe caught in the Norwegian Sea and the North Sea had higher levels of undesirable substances compared to saithe caught in the Barents Sea.

4 Crustaceans

Analyses indicate that foods with the highest levels of cadmium contamination are shellfish and the kidneys of animals such as pigs (Bendell, 2010; Järup et al., 1998). In Norway, the level of cadmium in edible crab, *Cancer pagurus*, has recently been monitored along the coast of northern Norway (Frantzen, Duinker & Måge, 2015). According to Commission Regulation (EC) No. 1881/2006 of the EU, the maximum limit of cadmium in samples of crustacean is 0.5 mg/kg wet weight (ww). Frantzen et al. (2015) reported the level of cadmium in the meat from edible crab to vary in the range of 0.13 to 1.50 mg/kg meat. This study revealed that the average level of cadmium exceeded the maximum limit in 11 out of 20 samples.

Snow crab (*Chionoecetes opilio*) and king crab (*Paralithodes camtschaticus*) are high-priced commercial species that are mainly consumed in high-end markets in Korea, Japan and the United States of America (Anderson, Martinez-Garmendia & King, 2003; Lorentzen et al., 2014; Lorentzen et al., 2016). In our research, meat from snow crab and king crab has been analysed with respect to undesirable substances (Table 2). The snow crabs were collected from the Loophole in the Barents Sea in April 2015, while the king crabs were caught in the Varanger fjord in Northern Norway during November 2012. Before the sampling and killing, the snow crabs were starved for four weeks, while the king crabs were killed immediately after harvest. Snow crab meat includes protein, water, ash (including carbohydrates) and oil, with a distribution of 18.3, 79.6, 1.6 and < 0.5% respectively, while the corresponding values for king crab meat are 18.0, 78.3, 3.2 and < 0.5%. For both species, the level of cadmium and mercury in the meat was below the maximum limit (EU Commission Regulation (EC) No. 1881/2006). Since inorganic arsenic is more toxic than organic arsenic (Raber et al., 2012), levels of both organic and inorganic arsenic were determined and found to be below the set maximum levels. At present, no maximum limit is set by the EU for total arsenic, inorganic arsenic and manganese. However, based on the results from this study, it is concluded that meat from snow and king crab is safe to eat.

In a study by Julshamn et al. (2015), claw and leg meat of king crab was analysed for dioxins, furans, non-ortho and mono-ortho PCBs, non-dioxin-like PCBs, polybrominated diphenyl ethers, arsenic, cadmium, mercury and lead. From April to November 2012, the king crabs were collected from different areas of the Barents Sea, including the Varanger fjord. The concentrations of persistent organic pollutants and metals in the king crab meat were low and below the maximum limits laid down by the EU, leading Julshamn et al. (2015) to conclude that red king crab is safe to eat.

5 Farmed Fish

Food safety of farmed fish has received increasing attention in recent years, especially with respect to environmental contaminants. The fish is farmed in net cages that are sited in sheltered bays along the Norwegian coastline. In the case of Atlantic salmon, it takes about 15-18 months for the fish to obtain a weight of approximately 4-5 kg from smolt stage.

Farmed fish are monitored frequently with respect to undesirable substances (Council Directive 96/23/EC). For every 100 tonnes of farmed fish produced, at least one fish is analysed. The NFSA performs sampling from the slaughterhouses and processing facilities on a regular basis. All these samples are analysed by the NIFES. In the last years, about 12,000 farmed fish have been analysed annually. Table 3 shows levels of undesirable substances such as arsenic, cadmium, mercury, lead and tributyltin in fillets of farmed fish, namely Atlantic salmon, rainbow trout and Atlantic cod, as reported by Hannisdal et al. (2015). Tributyltin includes a class of organic compounds and was used as an ingredient in anti-fouling paint applied to the hulls of boats.

The general trend for most contaminants analysed shows that the levels of undesirable substances in farmed salmon are declining significantly, reflecting the shift from fish-based to more vegetable-based raw materials in the feed. For example, the levels of dioxins have decreased from 1.4 ng TEQ/kg ww to 0.5 ng from 2002 to 2013, where TEQ refers to toxic equivalents of mixtures of polychlorinated dibenzodioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and PCBs and is used for risk characterisation. The present World Health Organisation (WHO) scheme is represented as TEQ/WHO. Since 2005, when the metals were included in the monitoring programme, the level of mercury and arsenic declined from 0.037 to 0.014 mg/kg ww and from 2.00 to 0.55 mg/kg ww respectively.

Occasionally, drugs are used in fish farming. The use of antibiotics in Norwegian fish farming is low and less than 1.0 mg/kg farmed fish. About 0.5 to 1.0% of farmed fish has been treated with antibiotics (Utne Skåre et al., 2015). Norwegian legislation concerning residues of drugs in fish is similar to EU legislation. Fish treated with drugs are held in quarantine (withdrawal time) to make sure that the levels of residuals are below maximum limits. The fish farmer and the veterinarian are responsible for keeping the withdrawal time, the latter depending on drugs applied, size of the fish and water temperature. If drugs are used, this is reported to the NFSA.

From time to time, a parasitic nematode, *Anisakis*, is present in wild caught fish. *Anisakis* species are infective to humans as they can cause anisakiasis. Fish products that are intended to be consumed raw are kept at -24 ^{0}C for a minimum of 24 hours to kill the parasite. To our knowledge, *Anisakis* has not been detected in farmed salmon. The most apparent explanation of this is that the fish feeds on dry feed, which is unlikely to contain parasites. Based on these facts, the NFSA considers it safe to consume raw farmed salmon, as in sushi and sashimi, without any freezing in advance.

The prevalence of the pathogen *L. monocytogenes* in raw and ready-to-eat seafood and fish products, especially in smoked fish, can be up to 25% (Farber, 1991). Salmon is one of

Table 1. Concentrations (mg/kg ww) of arsenic, mercury, cadmium and lead in muscle and liver of saithe from the North Sea; mean, standard deviation (SD), median, minimum and maximum values and number of fish with concentrations below the limit of quantification (LOQ) are given (Copyright ©2013 Nilsen et al.; reproduced with permission)

Element (mg/kg ww)	Mean[1]	SD[1]	Median	Min	Max	#< LOQ	EU limit
Arsenic in muscle (*N* = 664)	2.9	2.1	2.5	0.37	15	0	--
Arsenic in liver (*N* = 636)	6.5	4.6	5.6	0.86	41	0	
Mercury in muscle (*N* = 664)	0.066	0.037	0.057	0.015	0.35	0	0.5
Mercury in liver (*N* = 636)	0.020	0.019	0.015	< 0.003	0.19	22	
Cadmium in muscle (*N* = 664)	0.0016	0.0011	0.0010	< 0.001	0.010	271	0.05
Cadmium in liver (*N* = 636)	0.32	0.24	0.28	< 0.004	1.8	1	
Lead in muscle (*N* = 664)			< 0.006	< 0.006	0.075	637	0.3
Lead in liver (*N* = 636)			< 0.02	< 0.02	0.40	590	

[1]Mean and standard deviation (SD) were not determined in cases where more than half the number of fish had concentrations below the LOQ.

Table 2. Concentrations of undesirable substances in meat from snow crab and red king crab. The samples were obtained from legs from 10 crabs

Element	Snow crab meat	King crab meat	EU limit
Arsenic (mg/kg ww)	112.00	8.29	--
Cadmium (mg/kg ww)	0.0140	0.0035	0.50
Mercury (mg/kg ww)	0.1190	0.0539	0.50
Manganese (mg/kg ww)	0.195	0.221	--
Zinc (mg/kg ww)	31.00	22.00	--
Sum PCB (TEQ)/WHO)[1]	< 0.24	NA[2]	
Sum PCDD/PCDF (TEQ/WHO)	< 0.36	NA	

[1]Includes PCB 77, PCB 81, PCB 105, PCB 114, PCB 118, PCB 123, PCB 126, PCB 156, PCB 157, PCB 157, PCB 167, PCB 169 and PCB 189 [2]NA = not analysed

Table 3. Concentrations of arsenic, mercury, cadmium, lead and tributyltin in fillets of farmed fish; no mean or median is given if more than 50% of the results are below the limit of quantification (LOQ) (Copyright ©2015 Hannisdal et al.; reproduced with permission)

Element		Atlantic Salmon	Rainbow trout	Atlantic Cod	Atlantic halibut	LOQ	EU limit
Arsenic (mg/kg ww)	*N*	105	8	2	1		
	Median	0.58	0.62	0.62			
	Max	2.1	1.0	0.63	1.6	0.003	
Cadmium (mg/kg ww)	*N*	105	8	2	1		
	Max	0.002	LOQ	LOQ	LOQ	0.001-0.003	0.050
Mercury (mg/kg ww)	*N*	105	8	2	1		
	Median	0.019	0.018	0.042			
	Max	0.059	0.035	0.043	0.069	0.002	0.50
Lead(mg/kg ww)	*N*	105	8	2	1		
	Max	0.026	LOQ	LOQ	LOQ	0.005-0.01	0.30
Tributyltin (⅛g/kg ww)	*N*	59	4	2	0		
	Max	0.60	LOQ			0.3-0.5	

Table 4. Concentrations of PCB-28, PCB-52, PCB-101, PCB-138, PCB-153 and PCB-180 and sum PCB6 in fish feed, fishmeal and fish oil for 2014; values are given as μg/kg sample with mean value and range[1]

	PCB-28 (μg/kg)	PCB-52 (μg /kg)	PCB-101 (μg /kg)	PCB-138 (μg /kg)	PCB-153 (μg /kg)	PCB-180 (μg /kg)	Sum PCB6 (μg /kg)
Fish feed (*N* = 73)	0.3	0.5	1.0	1.5	2.5	0.7	6.5
Min-Max	0.1-0.7	0.1-0.4	0.1-3.0	0.2-5.0	0.3-8.0	0.1-2.3	0.8-20.4
Fishmeal (*N* =10)	0.3	0.5	1.1	2.0	2.8	0.7	7.4
Min-Max	< 0.04-0.6	< 0.04-1.0	0.1-1.8	0.1-5.0	0.1-6.0	< 0.04-1.4	0.3-15.2
Fish oil (*N* = 7)	2.5	4.6	9.5	12.7	21.6	6.5	56.0
Min-Max	< 0.2-5.0	< 0.2-10.0	0.6-21.0	1.0-28.0	1.5-48.0	0.8-14.0	3.8-120.0

[1] Data reported in Sanden et al. (2015)

several potential sources of the pathogen. The presence of *L. monocytogenes* was investigated in three Norwegian companies processing salmon (Lunestad, Truong & Lindstedt, 2013). In this study, 15 types of *L. monocytogenes* were detected. Among these, nine strains belonged to a genetic variant similar to that found in patients with listeriosis. To our knowledge, no cases of listeriosis have been linked to the consumption of salmon. The limited numbers of listeriosis cases reported might be due to levels below the infective dose of 100 colony-forming units (CFU)/g (or ml), which is insufficient to cause illness in most healthy consumers. This assumption is supported by the fact that this pathogen has been isolated from 1-6% of faecal samples from healthy people (Ooi & Lorber, 2005; Rocourt & Cossart, 1997).

6 Fish Feed

Food safety issues of farmed fish have been predominantly related to fish feed. Thus, considerable resources have been allocated to monitor fish feed frequently. In 2014, a total of 126 samples were analysed with respect to PCBs, including 78 feeds, 10 fishmeals, 10 plant proteins, 12 plant oils and seven fish oils (see findings reported by Sanden et al. (2015) in Table 4). The NFSA is notified in the case of non-compliant results. With the exception of one non-compliant complete feed containing the pesticide hexachlorobenzene (HCB), results showed that all samples of feed and feed ingredients were compliant with regard to the maximum levels of heavy metals and organic contaminants. One of the feed samples exceeded the maximum limit with respect to cobalt, copper, manganese, iodine and zinc, while several of the feed samples exceeded the maximum limit with respect to vitamin D3 and selenium.

7 Conclusion

Overall, consumption of seafood from Norway involves low risk of negative health effects. This may be due to a thorough knowledge of food safety risks, a comprehensive monitoring programme for seafood safety and a strict regime of fish farming in Norway.

Utne Skåre et al. (2015) have carried out a comprehensive assessment of the available scientific literature on the positive health effects of seafood consumption, the contribution of fish to the intake of beneficial substances, as well as exposure to hazardous contaminants in Norway. They concluded that the benefits clearly outweigh the negligible risk presented by current levels of contaminants and other known undesirable substances in seafood.

It is foreseen that more information about the effects of climate change in terms of food safety issues will be required. Such information should address the effects of an elevated sea temperature and increased acidification. In addition, climate change might also generate extreme weather, which is expected to have consequences for biodiversity, the aquaculture industry, maritime transport and infrastructure. If climate change or any other conditions are found to affect seafood safety, the NFSA and NIFES will take this into account and adjust the monitoring programme accordingly.

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9 Conflicts of Interest

The authors report no conflicts of interest.

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