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Microbiological assessment along the fish production chain of the Norwegian pelagic fisheries sector – Results from a spot sampling programme

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ABSTRACT

Microbes play an important role in the degradation of fish products, thus better knowledge of the microbiological conditions throughout the fish production chain may help to optimise product quality and resource utilisation. This paper presents the results of a ten-year spot sampling programme (2005–2014) of the commercially most important pelagic fish species harvested in Norway. Fish-, surface-, and storage water samples were collected from fishing vessels and processing factories. Totally 1 181 samples were assessed with respect to microbiological quality, hygiene and food safety. We introduce a quality and safety assessment scheme for fresh pelagic fish recommending limits for heterotrophic plate counts (HPC), thermos tolerant coliforms, enterococci and *Listeria monocytogenes*. According to the scheme, in 25 of 41 samplings, sub-optimal conditions were found with respect to quality, whereas in 21 and 9 samplings, samples were not in compliance concerning hygiene and food safety, respectively. The present study has revealed that the quality of pelagic fish can be optimised by improving the hygiene conditions at some critical points at an early phase of the production chain. Thus, the proposed assessment scheme may provide a useful tool for the industry to optimise quality and maintain consumer safety of pelagic fishery products.

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1. Introduction

Fisheries around the world provide food and income, along with traditional cultural identity. Worldwide, the annual fish catches landed in 2006–2012 were stable at around 90 million metric tonnes, with the largest volumes originating from marine fisheries. During this period, the Peruvian anchoveta (*Engraulis ringens*) was caught in highest volumes, followed by Alaska pollock (*Theragra chalcogramma*), skipjack tuna (*Katsuwonus pelamis*), Atlantic herring (*Clupea harengus*), and chub mackerel (*Scomber japonicus*) (Food and Agriculture Organization, 2014). Some pelagic fish species comprise the largest proportion of the marine catches since large volumes are still used in animal feed production, *i.e.* not directly intended for human consumption (Tacon and Metian, 2009). According to the Directorate of Fisheries, the pelagic fisheries sector in Norway comprises more than 100 ocean-going vessels, and about 150 fish processing operators. The catching volume accounted for half of the total Norwegian wild catch fisheries, exceeding 1.2 million tonnes in 2014. This gave a first-hand value of 4.9 billion NOK, with Atlantic mackerel (*Scomber scombrus*), herring (*C. harengus*), blue whiting (*Micromesistius poutassou*) and capelin (*Mallotus villosus*) accounting for around 90%. Herring contributes with one third of both catch volume and value, whereas Atlantic mackerel is the most valuable pelagic species per weight of freshly landed fish (Directorate of Fisheries (2014)). Approximately 85% of Atlantic mackerel and herring landed in Norway are bound for export, with Russia, Denmark, China, and Japan as the main markets (Norwegian Seafood Council, 2014). The global demand for high quality food resources is expected to increase steeply, and since most wild captured fish stocks are already fully exploited, or even over-exploited, a further increase in demand for fishery products must be based on better and more efficient utilisation of the already harvested resources. Globally, as much as 25% of the fish are wasted post-harvest (Food and Agriculture Organization, 2015), and the responsibility to optimise the utilisation of the resources lies to a large extent within the fish industry.

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Along the chain, from capture to landing and processing, the fish is in contact with surfaces of handling equipment, as well as storage and washing water within the production environment. During this contact, contamination by microorganisms may occur through the water, personnel and inadequate cleaning procedures. Most pelagic fish are round-frozen at the factories, bound for export. Proper temperature control is essential during storage, transportation, and production, to minimize bacterial growth prior to freezing. Additionally, fish carry an indigenous microbiota that includes the specific spoilage bacteria (SSB) of fish (Svanevik and Lunestad, 2011) and in a few cases, potential human pathogens *e.g. Listeria monocytogenes* and *Clostridium botulinum* (Huss, 1997). The muscle tissue of healthy fish is assumed sterile upon catch, whereas bacteria are typically found on all outer surfaces (skin, shell, and gills) as well as in the alimentary tract. Still, newly harvested fish from cold waters are usually considered to represent a low risk with respect to consumer hazards (Feldhusen, 2000; Painter et al., 2013), where scombrotoxin (*i.e.* histamine) intoxication is most frequently reported (Huss et al., 2000). Either way, the fish sector has to comply with challenges along the production line, including adequate cleaning- and disinfection routines (Regulation (EC) No 853/2004). Several studies have been performed to identify biohazards, and to analyse and calculate the risk of contamination of different food items during processing (den Aantrekker et al., 2003; Kusumaningrum et al., 2003; Pérez-Rodríguez et al., 2008), including marine species *e.g.* Atlantic salmon and Atlantic herring (Bagge-Ravn et al., 2003; Skåra et al., 2011). A Hazard Analysis and Critical Control Points (HACCP) plan is, however, not required for fishing vessels, as they are defined as primary producers. In addition to general requirements regarding production of safe food, the vessels are obliged, by regulation, to use clean tools and clean water (FOR-2008-12-22-1623).

Heterotrophic plate counts are important indicators of fish quality and cleanliness at various contact points on board of fishing vessels and in processing factories. The presence of hydrogen sulphide (H_2S) producing bacteria indicates the remaining shelf life, as the proportion of H_2S-producing bacteria normally is low immediately post capture, but increases during storage and processing. As most food borne pathogens are transmitted through the faecal-oral route, strict rules concerning hygiene apply to all food producers. To assess the hygienic conditions in the production environments, analyses for specific indicator organisms of faecal contamination would be needed. In the present study, the coliforms, thermo-tolerant coliforms, and presumptive *Escherichia coli*, as well as enterococci, were in focus. To assess the food safety, the examination of different pathogenic species are required. *L. monocytogenes* occurs naturally in marine environments influenced by run off from land, and could therefore follow the fish throughout the production line. Other bacteria, such as *Staphylococcus aureus* and *Salmonella*, are more often associated with cross-contamination during production. Thus, as a human pathogen, *Salmonella* is of much greater concern for seafood in the southern parts of Europe and in the US (Amagliani et al., 2012), as members of this group are rarely found in fish products in Norway, but sometimes in fish feed and at the fish feed factories (Lunestad et al., 2007). Nevertheless, analyses are included to ensure the absence of these bacteria for the export market.

In this paper we introduce an assessment scheme to evaluate the microbiological conditions of fresh fish, surfaces and production water along a production line. The scheme was applied on the results from ten years of spot sampling in the Norwegian pelagic fish sector. Samples were assessed for quality, hygiene, and food safety, aiming to improve and further optimize quality of fish products during production.

2. Materials and methods

2.1. Location and species

The present study focused on Atlantic mackerel (*S. scombrus*), two herring stocks (*C. harengus*, North Sea- and Norwegian spring spawning (NSS) herring), blue whiting (*M. poutassou*), and Barents Sea capelin (*M. villosus*). The study followed the catch through the entire production line under authentic commercial conditions. This included purse seiners and trawlers of the Norwegian ocean-going fishing fleet, all equipped with laboratory facilities, and various fish processing factories. Forty-one (41) samplings were carried out, where seven fishing vessels (Vessel A-G) were involved in 29 different samplings, including mackerel (15), North Sea herring (6), NSS herring (3), blue whiting (4), and capelin (1). Additionally, six different factories (Factory A-F) were examined at 12 different samplings which included mackerel (10) and NSS herring (2). Samples of fish and contact points (surfaces and water) were collected from all vessels and factories, however, not necessarily on every cruise. One exception was Vessel E, where no water samples were taken. All samplings are listed in Table 1. It should be noted that, given the large number of vessels and factories involved in the Norwegian pelagic fisheries, our samplings reflect only a small fraction of the annual production volume. However, the Norwegian pelagic industry is characterised by comparatively young vessels (most built in 2005 or later) and modern processing factories which use basically the same technology (and supplier). Thus, our samples reflect most likely an average microbiological situation within the sector.

2.2. Samples

During the sampling period, 628 fish were sampled and analysed at both commercial fishing vessels (453) and fish processing factories (175). Fish samples were aseptically collected by hand, with glows washed with 70% ethanol, and put in sterile sampling bags prior to storage on ice for transportation to the laboratory. On board the vessels, fish were collected from the refrigerated seawater (RSW) tanks prior to landing, whereas at the fish processing factories, fish were collected from the landing tanks, as well as at different critical stages throughout the production line.

Samples collected from the surfaces of equipment and water associated with fishing and processing are collectively referred to as contact point samples (*i.e.* water and surfaces in contact with the fish). From vessels, surface samples were collected from the pump nozzle, sift box, sorting chamber, RSW storage tank, tubes, and outlets, primarily before capture. At some samplings, we examined the purse seine or trawl bag. Seawater samples were taken during on-board pumping, and from the RSW tanks prior and after storage of fish, and kept in sterile 500 ml bottles. At the factories, surface samples included conveyor belts, sorting and filleting machines, in addition to surfaces of water drains in the production area. Water samples were taken from the landing tanks, either seawater or tap water, and different washing tanks inside the factory holding potable water. Some samples were collected from the clothing of the workers that were in contact with the fish. Overall, 533 contact point samples were examined.

2.3. Heterotrophic plate count and H_2S-producing bacteria

The heterotrophic plate count (HPC) of fish samples were examined by cultivation using Iron Agar Lyngby (Oxoid), which also gives the number of H_2S-producing bacteria as black colonies, due to precipitation of iron sulphide (FeS) (Gram, 1992; Gram et al., 1987). Preparation was done according to the Nordic Committee

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