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SCIENTIFIC OPINION

Food Safety considerations of animal welfare aspects of husbandry systems for farmed fish[1]

(Question No EFSA-Q-2008-297)

Adopted on 23 October 2008

Relating to Opinions of the Scientific Panel on Animal Health and Welfare:

Animal welfare aspects of husbandry systems for farmed fish - European eel
EFSA-Q-2006-150 Adopted 11 September 2008[2]

Animal welfare aspects of husbandry systems for farmed fish -
Sea bass and gilthead seabream
EFSA-Q-2006-149 Adopted 22 October 2008[3]

Animal welfare aspects of husbandry systems for farmed fish - Carp species
EFSA-Q-2006-148 Adopted 22 October 2008[4]

Animal welfare aspects of husbandry systems for farmed fish - Trout species
EFSA-Q-2006-147 Adopted 11 September 2008[5]

Animal welfare aspects of husbandry systems for farmed fish - Atlantic salmon
EFSA-Q-2006-033 Adopted 19 June 2008[6]

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2 www.efsa.europa.eu/EFSA/efsa_locale-1178620753812_1211902132140.htm

3 www.efsa.europa.eu/EFSA/efsa_locale-1178620753812_1211902193915.htm

4 www.efsa.europa.eu/EFSA/ScientificPanels/ahaw/efsa_locale-1178620753812_Opinions5.htm

5 www.efsa.europa.eu/EFSA/efsa_locale-1178620753812_1211902132105.htm

6 www.efsa.europa.eu/EFSA/efsa_locale-1178620753812_1211902014109.htm

SUMMARY

The European Commission asked the Scientific Panel on Biological Hazards of the European Food Safety Authority to consider the Food Safety aspects of animal welfare of husbandry systems for several species of fish farmed in the EU. In this opinion, the BIOHAZ Panel has focused on the food safety relevance of pre-harvest factors relating to fish welfare, in one opinion incorporating aspects regarding six species (Atlantic salmon, gilthead sea bream, sea bass, trout species, carp species and European eel). Only biological risks have been assessed, as consideration of the occurrence and principles of control of chemical residues (including mycotoxins and marine toxins) in farm animals is outside the mandate of the BIOHAZ panel.

Farm location, the species being farmed, husbandry practices and environmental conditions are all factors that influence the food safety risk associated with aquaculture products. Risk is also influenced by post-harvest processing and practices and habits in food preparation and consumption. A major advantage of aquaculture in regard to food safety is that control can be exerted over the quality and safety of the product, and many of the hazards at the production level can be controlled by good aquaculture practices and safety management systems.

Specific information on the effect of welfare-related pre-harvest practices that may affect fish safety is scarce and knowledge gaps on the issues of fish welfare and their influence on food safety abound. Hence only general considerations of relationships or effects identified, based on general principles of hygiene and safety, are presented in this opinion. As far as location is concerned, European farms are located in sub-arctic and temperate waters in coastal, brackish-water, and in inland freshwater habitats, with generally low levels of pathogenic micro-organisms and parasites as compared to other latitudes. The European aquaculture industry commonly implements fish health management and pre-harvest quality and safety control measures, contributing to a significant reduction of risks associated with biological hazards and, at the same time, achieving a high degree of control over the production process. Risks can be additionally controlled by hygienic processing and post-processing, preparation of foods and appropriate habits of food consumption.

Production procedures based on good aquaculture practices (as recommended in different industry codes of practice) that result in provision of optimal animal welfare increase fish resistance to infections and therefore may lead to a reduction of the food safety risks associated with the resulting end products. Measures intended to maintain fish welfare by avoiding stress or improving environmental conditions are expected to have a positive impact on the safety of the food product. Environmental and hygienic conditions (related to water temperature, salinity, chemicals, organic matter, oxygen levels, etc.) and practices at pre-harvest level (inadequate feeding or antimicrobial usage), could increase the prevalence of certain biological hazards at farm level, and may also have an effect on fish welfare and physiological condition (stress). Both these aspects impact on fish health, and subsequently may influence the safety of the end product.

Some aquaculture practices and conditions inherent to specific production methods may influence the safety of the food product. Intensive systems give producers a better opportunity to manage biological risks by using water and feed quality control, biosecurity, health management, and vaccination. On the other hand, some conditions (mostly associated with handling and crowding) occur more commonly in intensive systems and, if not properly managed, they may act as stressors, increasing the risk of pathogen carriage and disease. Extensive systems have a lower degree of intensification and avoid excessive handling and crowding, therefore, are in principle less stressful. On the other hand, and when control can not be fully exerted over risk factors (such as non-optimal feeding, poor water quality and poor fish health), there are more opportunities for pathogen carriage and disease. In all cases, pre-harvest measures are to be complemented by the best practices at the post-harvest level.

Extension of coordinated animal welfare / food safety research programs should be encouraged in order to improve the desired synergism between the two approaches.

Key words: Fish, welfare, zoonoses, risk factors, food safety, public health

TABLE OF CONTENTS

BACKGROUND AS PROVIDED BY EUROPEAN COMMISSION

Council Directive 98/58/EC concerning the protection of animals kept for farming purposes lays down minimum standards for the protection of animals bred or kept for farming purposes, including fish.

In recent years growing scientific evidence has accumulated on the sentience of fish and the Council of Europe has in 2005 issued a recommendation on the welfare of farmed fish[7]. Upon requests from the Commission, EFSA has already issued scientific opinions which consider the transport[8] and stunning-killing[9] of farmed fish.

TERMS OF REFERENCE AS PROVIDED BY EUROPEAN COMMISSION

In view of this and in order to receive an overview of the latest scientific developments in this area the Commission requests EFSA to issue a scientific opinion on the animal welfare aspects of husbandry systems for farmed fish. ***Where relevant, animal health and food safety aspects should also be taken into account.*** This scientific opinion should consider the main fish species farmed in the EU, including Atlantic salmon, gilthead sea bream, sea bass, rainbow trout, carp and European eel and aspects of husbandry systems such as water quality, stocking density, feeding, environmental structure and social behaviour.

ACKNOWLEDGEMENTS

The European Food Safety Authority wishes to thank Miguel Prieto Maradona for the preparation of this opinion.

7 Recommendation concerning farmed fish adopted by the Standing Committee of the European Convention for the protection of animals kept for farming purposes on 5 December 2005

8 Opinion adopted by the AHAW Panel related to the welfare of animals during transport -30 March 2004

9 Opinion of the AHAW Panel related to welfare aspects of the main systems of stunning and killing the main commercial species of animals- 15 June 2004

ASSESSMENT

1. Introduction

The Animal Health and Welfare Panel (AHAW) has addressed animal welfare aspects of aquaculture production systems for six species (Atlantic salmon, gilthead sea bream/sea bass, rainbow trout, carp and European eel) in form of five separate scientific Opinions[2,3,4,5,6]. In this opinion, the BIOHAZ Panel has focused on the food safety relevance of pre-harvest factors relating to fish welfare, in an individual opinion incorporating all aspects addressed by the AHAW Panel Opinions. In most, if not all of the conditions or factors considered, there is limited or unavailable evidence of a quantifiable and directly applicable relationship between animal welfare-relevant factor (on-farm) and safety hazard (at slaughter). Therefore, only brief descriptive considerations of any such relationships identified, based on general principles of hygiene and safety, are presented in this opinion.

Potential biological hazards in aquaculture products comprise bacteria, viruses, biotoxins and parasites (WHO, 1999; Huss, 2002; Huss *et al.*, 2003). Main factors influencing the risk associated with those products include the farm location, the species being farmed, husbandry practices and systems (including feeding), post-harvest processing, and eating habits in food preparation and consumption. The major advantage of aquaculture in regards to food safety is that the producer can exert control over the quality of the product, and many of the hazards at the production level can be controlled by good aquaculture practices (GAP) and safety management systems. These practices and systems should be compatible with animal welfare and take into account environmental protection aspects.

There are many knowledge gaps on the issues of fish welfare and their influence on food safety. There is no specific information on the effect of welfare-related pre-harvest practices that may affect fish safety. Published scientific literature on fish safety deals mainly with hazards concerning fish farmed in temperate waters, mainly in intensive aquaculture systems such as freshwater raceway farming, marine net pen and cage culture systems. The six fish species considered in this report (Atlantic salmon, gilthead sea bream, sea bass, trout species, carp species and European eel) are farmed under very different production systems (for a summary of production systems and particular aspects of the species, see AHAW Opinions[2,3,4,5,6]). Other farmed species not included have lower production volumes in the European Union, and shellfish is out of the scope of this mandate. It should be emphasized that the aquaculture industry in Europe commonly implements health management and pre-harvest quality control measures. These are highly elaborated management systems in place in the production systems commonly used for the species concerned in this opinion. According to the water management system, stocking density, feeding regime and feedstuff employed, several management types can be depicted with a continuum in the levels of intensification: from extensive, through semi-intensive and intensive to super-intensive (for a description of production and feeding systems, see AHAW Opinions[2,3,4,5,6]. As far as location is concerned, European farms are located in sub-arctic and temperate waters in coastal, brackish-water, and in inland-freshwater habitats, with generally low levels of pathogenic micro-organisms and parasites as compared to other latitudes. All these factors contribute to a significant reduction of risks associated to biological hazards and, at the same time achieve a high degree of control over the biological production process.

This document primarily covers the pre-harvest stages of the aquaculture production systems. Of all the biological phases (larvae, fry/fingerling/juveniles, ongrowers, broodstock), attention has been paid to the ongrowers (animals in the raising process after the initial larval/juvenile stages to a marketable size). It is agreed that the closer the risks occur to the time of slaughter, the higher is their food safety importance. Some stages, not considered pre-harvest, such as transport, feed deprivation and stunning, could also influence the safety of fish products. The experts acknowledge that some biohazards, such as *Listeria*, would be of greater importance during post-harvest stages. However the terms of reference of the mandate indicate that the focus of the risk assessment should be with the husbandry systems and conditions.

A comprehensive list of hazards identified in aquaculture production systems and a qualitative estimation of their associated risk, based on published literature is presented here. It should be noted that the associated risk is frequently very low due to low occurrence of pathogens in the systems and conditions mentioned, the implementation of risk management measures not only at pre-harvest stages but during harvesting and processing, and the hygienic preparation of foods before consumption. In this opinion, only biological risks have been assessed. Furthermore, the mandate is limited to the evaluation of associated risks in relation to factors affecting welfare of farmed fish. As consideration of the occurrence and principles of controls of chemical residues (including mycotoxins, and marine toxins) in farm animals is outside the mandate of the BIOHAZ panel, these issues will not be dealt with in this opinion.

2. Biological hazards in aquaculture fish

2.1. Bacteria

Scientific reviews of bacterial hazards in fish group them together into those who are indigenous to the aquatic environment, where the fish is caught; those occurring as result of faecal contamination, and those introduced during post-harvest and processing (Howgate, 1998; WHO, 1999; Huss *et al*., 2003). Some pathogenic bacteria are considered indigenous to the aquatic environment (*Vibrio, Aeromonas*, *Plesiomonas*, non-proteolytic *Clostridium botulinum*). They generally occur in low numbers in water, and their prevalence and concentration is dependent on environmental conditions (temperature, salinity, oxygen content, presence of organic matter, phyto- and zooplankton) (Kirov, 1997; Oliver & Japer, 1997). Occurrence of some other pathogens in water and fish (*Salmonella, Shigella,* pathogenic *Escherichia coli, Campylobacter, Yersinia*) is generally due to external contamination sources (such as farms located in polluted areas, use of excreta as fertilizers, faecal effluents from human sewage, farms or wild animals), but they can also be introduced during processing. *Listeria monocytogenes* and proteolytic types of *C. botulinum* are ubiquitous bacteria and can also be found on fish.

2.1.1. Clostridium botulinum

Non proteolytic *Clostridium botulinum* type E has been frequently implicated in fishborne intoxications due to consumption of industrially processed raw smoked salmon and trout (Anonymous, 1998; Bach *et al.*, 1971; Baumgart, 1970; Dressler, 2005; Hauschild & Gauvreau, 1985). Toxinogenesis from psychrotrophic, non proteolytic types may precede organoleptic spoilage in extended shelf-life fish products (Baker *et al.*, 1990). *C. botulinum* type E seems to be an authentic aquatic organism. It occurs in sediments of lakes, ponds and sea where apparently anoxic conditions and presence of carrion allow proliferation. *C. botulinum* type E has been isolated from fish gills, skin and intestines and apparently fish (trout, salmon) is a transient carrier of spores (Ala-Huikku *et al*., 1977; Burns & Williams, 1975; Hielm *et al*., 1998b; Hielm et al., 2002; Huss & Eskildsen, 1974; Pullela *et al.*, 1998). Spores of *C. botulinum* type E have a marked geographic distribution (Dodds & Austin, 1997), with high occurrence off the coast of Greenland, the Baltic Sea and the North Sea (Hielm *et al.*, 1998a, b;

Hielm *et al*., 2002; Huss, 1980; Johanssen, 1963), and low in other environments investigated like shores of Iceland, Faroe Islands, Ireland and Great Britain (Cann *et al.*, 1965; Huss, 1980). These differences are also observed in freshwater sediments from pond farms and rivers (high occurrence in Finland (Hielm et al, 1998b; Hielm et al., 2002), low in inland waters in Iceland, Great Britain and Ireland (Smith *et al*., 1978). Its occurrence in marine or freshwater salmon and trout farms is associated with unhygienically managed or mud-bottomed farms where fish have access to sediments or carrion (Cann & Taylor, 1982; Hielm, 2002).

Other *C. botulinum* types such as type A, B and C have also been isolated from fish (Baker et al., 1990; Dodds & Austin, 1997).

2.1.2. Pathogenic vibrios

Prevalence of pathogenic vibrios in waters depends on environmental factors such as water temperature, salinity, and phytoplankton concentration (Tamplin, 2001). Vibrios are frequently isolated in tropical and subtropical aquaculture systems (prawns, oysters), as well as in estuarine waters (Balakris-Nair *et al*., 1991; Dalsgaard *et al*., 1998; Reilly & Twiddy, 1992). Its presence has been also reported in Europe, where levels are generally low except in bivalves (Arias *et al.*, 1998; Bauer *et al.*, 2006; Dumontet *et al*., 2000; Hervio-Heath *et al*., 2002; Hoi *et al.*, 1998a,b; Normanno *et al.*, 2006). *Vibrio parahaemolyticus, V. cholerae*, and *V. vulnificus* are the principal *Vibrio* species linked to seafood-borne infections, but there are at least 12 different human pathogenic species described, while some of these species are also pathogenic for fish (*Vibrio parahaemolitycus, V. vulnificus, V. damsela, V. anguillarum, V. alginolyticus*). It should be emphasized that non pathogenic clones also exist for some of the species above cited. Most cases reported in Europe are wound infections caused by seawater or seafood exposure, which can become systemic and compromise life in susceptible people. Foodborne infections caused by *Vibrio parahaemolyticus* are almost exclusively associated with the consumption of raw or undercooked fish and shellfish. Prevalence is very high in Asian warm coastal waters as well as fish and shellfish, but it less frequently reported in products or waters in Europe (Davies et al., 2001; European Commission, 2001; Hervio-Heath *et al.*, 2002; Huss *et al.*, 2003; Lozano-Leon *et al.*, 2003; Martinez-Urtaza *et al.*, 2004b). Recently, the pandemic clone O3:K6 has been isolated in Europe (Martinez-Urtaza *et al.*, 2005). There are occasional reports of non-O1/non-O139 *V. cholerae* isolations in European waters (Hervio-Heath *et al.*, 2002), but they are frequently reported in aquaculture products from other latitudes (Varma *et al*., 1989). There are no confirmed reports of cases of septicaemia and gastrointestinal disease caused by pathogenic vibrios following consumption of aquaculture fish products other than shellfish (Dalsgaard, 1998; WHO, 1999).

2.1.3. Aeromonas hydrophila

A. hydrophila is a farmed fish pathogen causing haemorrhagic septicaemia. This bacterium is part of the normal aquatic flora, and it is commonly found in fresh and brackish waters, as well as in fish in Europe (Davies *et al*., 2001; Gonzalez-Rodriguez *et al*. 2002). It causes wound infections in exposed persons handling fish or in contact with water. According to the WHO (WHO, 1999), epidemiological evidence suggests that public health risks from *Aeromonas* spp. in farmed fish are low.

2.1.4. Plesiomonas shigelloides

Its primary habitat is the aquatic environment (tropical and subtropical latitudes) and it has been isolated from fish and seafood (raw oysters, mainly) (Nedoluha & Westhoff, 1993), and very occasionally from freshwater environments in cold climates (Gonzalez *et al*., 1999; Krovacek *et* *al*., 2000). Its role in gastroenteritis disease is still unclear (Huss *et al*., 2003). The WHO report (WHO, 1999) attributes a low public health risk to farmed fish from *Plesiomonas shigelloides*.

2.1.5. Enteric bacteria

It is generally agreed that *Salmonella* and other enteric pathogens are not aquatic microorganisms and their presence in water or fish is due to contamination, as a result of poor hygiene standards (including contaminated feed) or run-off waters from human sewage, livestock farming, or industry (Martinez-Urtaza & Liebana, 2005a.b; Reilly & Twiddy 1992). Some studies have linked environmental factors to the presence of certain *Salmonella* serotypes in marine environments (Martinez-Urtaza *et al*., 2004c). Also there are reports of a seasonal change in occurrence depending on changes in human population in coastal areas (Martinez-Urtaza *et al*., 2004a). It is accepted that these micro-organisms are uncommon contaminants in farms located in temperate climates, although they can be present as a result of contamination with human or animal faeces. Some of these bacteria (*Salmonella*) have been isolated in tropical aquaculture systems (ponds) where faecal wastes were not used as fertilizers (Dalsgaard, 1998; Reilly & Twiddy 1992; WHO, 1999). Apparently the bacterium is unable to multiply within the aquatic environment in temperate waters and fish intestine is not its normal habitat (Dalsgaard, 1998). The same consideration applies to other enteric bacteria such as pathogenic *E. coli*, *Shigella* spp*.*, *Yersinia enterocolitica*, and *Campylobacter* spp. However when contamination occurs some *Salmonella* serotypes can persist in the marine environment for months, even years (Gaulin *et al*., 2002; Martinez-Urtaza & Liebana, 2005a).

2.1.6. Listeria monocytogenes

Seafood, including smoked salmon and trout which are consumed raw or undercooked, has caused outbreaks of listeriosis (Ericsson *et al.*, 1997; Lyytikinen *et al.*, 2006; Miettinen *et al.*, 1999). *Listeria* spp. is normally isolated from decaying plant material, and agriculture run-off waters can be a source of contamination. Unpolluted seawater and ground waters used in aquaculture are generally free from *Listeria*, and fish from these environments are not contaminated (FAO, 2000). If present, it is normally in low numbers. Weather conditions can influence occurrence of *Listeria* spp. in the fish farm environment (Miettinen & Wirtanen, 2006). *L. monocytogenes* can have also access to the fish through contaminated feed, agricultural run-off, or contaminated sediment in farming pens (FAO, 2000). Raw fish materials have been proven to be a source of contamination for final products (Eklund *et al.*, 1995; Jinneman, 1999; Miettinen & Wirtanen, 2006). Molecular typing studies have proven that the same clones are present in raw fish, processing environment and final product (Miettinen & Wirtanen, 2006). Other longitudinal studies on *Listeria* ecology indicate that contamination of the final product (cold-smoked salmon) occurs mainly at processing level due to this pathogen persisting in food-processing environments (Fonnesbech-Vogel *et al.*, 2001; Hansen *et al.*, 2006). It is assumed that fish can be contaminated at any point between pre-harvest and consumption. Taking together these studies indicate that control of this hazard should be performed at pre- as well as post-harvest stage.

2.1.7. Other zoonotic bacterial agents

Some zoonotic bacterial agents occurring in fish can cause systemic infections and threaten life in humans (European Commission, 2003; Hastein *et al.*, 2006). They occur in humans mostly as a result of fish handling (aquaculture or recreational fish, because of penetrating wounds caused by fins and spines), or after exposure to waters (Bisharat & Raz, 1996; Ghittino *et al*, 2003). Foodborne transmission is very rare, and would be limited to foods eaten raw or undercooked (Ghittino *et al.*, 2003).

Several species of mycobacteria (*Mycobacterium marinum*, *M. fortuitum*, *M. chelonae*, *M. shottsii*) can cause chronic disease in fish. *Mycobacterium marinum*, which causes the "fish tank granuloma" in workers handling infected fish (Huss *et al.*, 2003) has been isolated from ornamental and food fish (dos Santos *et al.*, 2002; Hastein *et al.*, 2006; Ucko *et al.*, 2002), but there are no reports of illness associated with the consumption of farmed finfish or crustaceans (WHO, 1999). *Erysipelothrix rhusiopathiae* and *Streptococcus iniae* are considered occupational hazards in people handling fish. Affected people are mainly those inmunocompromised which present wounds, abrasions. Risk of healthy people contracting the disease is very low. *Edwardsiella tarda* causes red disease in eels and fish septicaemia**.** In humans, it can cause gastroenteritis and generalized infection, which is usually through skin lesions (Acharya *et al.*, 2007), in immunocompromised individuals (Jordan & Gadley, 1969).

2.2. Viruses

Fish-borne disease by viruses is especially linked to the consumption of contaminated molluscan shellfish, and finfish has not been usually involved (WHO, 1999). Most reports associate molluscan bivalves with caliciviruses (such as noroviruses) and hepatitis A virus. This occurs in areas polluted with faecal effluents where biofiltration leads to concentration of virus particles in molluscs. It has not been demonstrated that viruses causing disease in fish be pathogenic to humans, and human viral diseases caused by the consumption of finfish and crustaceans appear to present a low risk (Shehadeh & McLean, 1997). Infectious salmon anaemia (ISA) has been pointed out as a possible zoonoses, but according to the Scientific Committee on Animal Health and Welfare, there is no reason to regard ISA as a zoonosis, and there is no evidence for risk to humans (Scientific Committee on Animal Health and Welfare, 2000).

2.3. Parasites

In most cases farmed fish has limited access to intermediate hosts if fed with formulated feed instead of raw fish (Hielm et al., 2002). Contact with wild fish can occur particularly in cage production. In some production systems, fish are wild caught and fed with fish for adaptation (eels). Parasites in farmed fish could also occur when there is interaction with endemically infested wild animals (as they try to feed on farmed fish). Also, introduction of a species for aquaculture into a new area may disseminate parasites and initiate a host parasite cycle. Helminths (trematodes, nematodes and cestodes) occurring in farmed fish are very rarely reported. The most important cestode in fish is *Dibothriocephalus (Diphyllobotrium) latus*. Among the nematodes, special attention has been dedicated to *Anisakis simplex*, whose prevalence in wild fish is high. According to the International Commission on Microbiological Specifications for Foods (ICMSF), *A. simplex* has never been detected in a large number of aquaculture salmon examined (ICMSF, 2003). European aquaculture products represent a low risk in regards to parasites. Other fishborne nematodes causing disease in humans are *Capilaria*, *Gnathosthoma*, and *Pseudoterranova* spp. Trematodes commonly infesting fish are *Clonorchis, Ophisthorchis, Paragonimus*, and to a lesser extent *Heterophyes*. In Chile, aquaculture salmon infested with *Dibothriocephalus latus* has been involved in an outbreak (Cabello, 2007).

2.4. Prions

There are several scientific opinions (SSC, 2003; EFSA, 2007a) which have addressed the issue of TSE in cultured fish. According to the BIOHAZ Panel, "currently there are no indications that natural TSEs occur in farmed or wild fish. However, this is based on very limited examination data both in terms of fish species examined, number of samples and detection methods applied. Feeding experiments in rainbow trout indicate that PrP_{sc} does not remain longer than 15 days in the fish intestine and does not cross the intestinal barrier either" (EFSA, 2007a). In addition, a deposition of plaque-like aggregates in the brain of one farmed species (seabream) after oral challenge with TSE agents has been observed, but no signs of disease were detected (Salta *et al.*, 2008)

2.5. Antimicrobial resistance

The use of antimicrobials to treat clinical infectious diseases on fish farms is necessary for animal health and welfare purposes. Antimicrobial usage, when necessary, should always be a part of an integrated animal health program, under veterinary supervision. Such usage is the subject of legislative controls for reasons related to public health, such as the development of antimicrobial resistance or the presence of residues in the fish. In European aquaculture antimicrobial usage has been traditionally very restricted and even more in the last few years with the development of vaccines and more strict legislation. The intensive use of chemotherapeutic agents to treat infectious diseases in aquaculture has led to an increased frequency of drug-resistant microorganisms, as well as bacteria showing multiple-antibiotic resistance. Several studies have reported the development of bacterial resistance to antimicrobials in different types of aquaculture production (Alderman & Hastings, 1998; Sørum, 2006). Foodborne antimicrobial resistance has been the subject of a recent EFSA opinion (EFSA, 2007c)**.** It has been previously highlighted the insufficient available information on antimicrobial resistance in some areas, especially aquaculture (WHO, 2004). Since then, a workshop organized by FAO/OIE WHO has evaluated risks associated to the use of antimicrobials in aquaculture, emphasizing the risk of spread of antibiotic resistance genes from aquatic and fish bacteria to human pathogens (FAO/OIE/WHO, 2006).

3. Brief overview of pre-harvest aquaculture farm factors affecting safety of the food product

Factors such as farm location, the species being farmed, husbandry practices and systems, post-harvest processing, and cultural habits of food preparation and consumption influence food safety risk associated with aquaculture products.

Biological stages comprise larvae, fry/fingerling/juveniles, ongrowers, broodstock but the focus of this opinion has been set on the ongrowers (animals in the raising process after the initial larval/juvenile stages to a marketable size). It is agreed that the closer the biological risks occur to the time of slaughter, the higher is their importance in food safety. It is also agreed that some stages, not considered pre-harvest, such as transport, feed deprivation and stunning, can have a large influence on safety. However, the terms of reference of the mandate indicate that the focus of the risk assessment should be with the husbandry systems and conditions.

3.1. Food safety relevance of water quality and environmental conditions

Prolonged changes in the water quality and environmental conditions act as stressors, making fish more susceptible to disease and pathogen carriage (FAO, 2008).

Environmental conditions (water temperature, salinity, oxygen levels, phytoplankton concentration, pH, light, nutrient conc. i.e., phosphorous, nitrogen) can modify the occurrence and concentration of indigenous aquatic pathogenic bacteria in water (*Vibrio* spp., *Aeromonas, Plesiomonas*) and therefore their occurrence in farmed fish (Tamplin, 2001; Martinez-Urtaza *et al.*, 2008). Development of blooms (red tides), which could eventually lead to the presence of toxic microalgae in fish, has also a strong dependence on environmental conditions. The impact of climate change on aquaculture has been highlighted as a possible future challenge (FAO, 2008). Changes in temperature, current, pH, nutrient inflow will definitely contribute to a modification in the distribution and concentration of harmful algae, contaminant loading, invasive species, and sources and vectors of animal and human disease agents in coastal and marine habitats. According to FAO (2008), climate change may exacerbate risks due to aquatic pathogens. An increase in prevalence for some pathogens (*Vibrio* spp.) as a result of extremely warm seasons has already been detected in European coastal areas (Gras-Rouzet *et al*. 1996; Høi et al., 1998b; Caburlotto *et al*., 2008). An evaluation of emerging risks should be performed to elucidate the scope of these issues. Several weather conditions (heavy rain, storm, floods) can have an impact on food safety, as it has been demonstrated that run-off waters can serve as vehicles for some pathogens (e.g. *Listeria monocytogenes)* increasing its prevalence in salmon, trout farms (Miettinen & Wirtanen, 2006). Environmental conditions can also influence water parameters (e.g. salinity) resulting in increased pathogen occurrence, (e.g. *Vibrio parahaemolyticus*) (Martinez Urtaza *et al*., 2008).

3.2. Food safety relevance of other stressors

All farmed species are susceptible to stress factors such as stocking density, grading, mixing of species, presence of predators, handling, transport, removal of fish from water, temperature changes or inadequate light regimes (for more information consult AHAW Opinions[2,3,4,5,6]). Stress factors, due to immunosuppression, increase susceptibility to fish diseases, and make fish prone to pathogen carriage. This may have particular importance for safety when occurring close to slaughter.

3.3. Food safety relevance of antimicrobial usage

The administration of antimicrobial drugs in fish production can adversely impact the environment, not only the farm site and farmed animals but also where the farm effluents are discharged or spread. Fish and human pathogens as well as aquatic saprophytic bacteria can develop resistance as a consequence of antimicrobial exposure. All of them can act as reservoirs of antimicrobial resistance genes that can be further disseminated, and ultimately end up in human pathogens, by transfer of resistance plasmids. Bacteria linked to aquaculture which have shown such antimicrobial resistance include *Aeromonas salmonicida, A. hydrophila, Edwardsiella tarda, Citrobacter freundii, Lactococcus garviae, Yersinia ruckeri, Photobacterium damselae* subsp. *piscicida*, *Vibrio anguillarum*, *Vibrio salmonicida*, *Photobacterium psychrophilum* and *Pseudomonas fluorescens* (Sørum, 2006). Emerging of resistance to important antimicrobials [such as quinolones, extended-spectrum cephalosporins, and methicillin (MRSA)] amongst microbial zoonotic and/or human pathogens is a public health concern, foodborne aspects of which have been evaluated in other BIOHAZ opinions (EFSA, 2007c).

3.4. Food safety relevance of vaccination

Vaccination should have a positive influence on food safety as it contributes to the improvement of the health status of the farmed fish, and reduces the need for the use of antimicrobials.

3.5. Food safety relevance of feeding

Safety issues regarding chemical compounds in feed are not the subject of this opinion. Food safety biological hazards associated with the use of compound aquaculture feeds may include *Salmonella* and other *Enterobacteriaceae* (Lunestad *et al*., 2007), and possibly prions. Feed manufacture should adhere to good manufacturing practices to minimize the associated risk (EFSA, 2007b). In the farming of carp in tropical or sub-tropical areas, the use of animal or human excreta as fertilizers to stimulate the natural production of food organisms is a common practice (Khalil & Hussein, 1997; Sharmaa & Olah, 1986; Islam & Tanaka, 2004; WHO, 2006), which can lead to an increased prevalence of enteric bacterial pathogens and parasites in the final product (on their surfaces and in their intestines) and when fish are grown under stressful conditions there may be penetration of edible fish tissues (WHO, 2006). When raw trash fish is used for fish feeding, infested or contaminated raw trash fish could result in parasitic infestations and bacterial infections of farmed fish. Feed should be appropriately handled and processed to avoid parasitic and bacterial contamination (refrigeration, cooking). If feed is not properly handled, proliferation of pathogens (e.g. *C. botulinum*) can take place (Hyytiä *et al.*, 1998). In relation to the use of MBM in fish feeding, currently no evidence has been found that a natural TSE exists in fish and there are no indications of replication of scrapie or BSE agent in experimental transmission studies. (EFSA, 2007a). Intra-species and intra-order recycling via feed is common practice in fish farming. This could increase the risk of amplification of infectious agents. Feeding of fish with plant proteins could be a viable alternative, however more research is needed with respect to the influence in fish health and welfare.

3.6. Food safety relevance of farm system and location

For a description of production and feeding systems, see AHAW Opinions[2,3,4,5,6].

Food safety hazards associated with aquaculture products vary greatly according to methods of production, farm management and location (Feldhusen, 2000; Howgate, 1998). Previously discussed factors are an integral part of the farm system. Fish species included in this opinion are raised in intensive/semi-intensive systems where environmental factors are controlled. Farm hygiene, biosecurity and sanitation are crucial in relation to animal health as well as safety of the fish product. Although most of the biosecurity and hygiene measures are specifically intended to reduce fish diseases, they will influence also the safety of the fish product. For trout as well as salmon, mud-bottomed farms (generally in ponds and net-cage farms) have increased probabilities of occurrence of *Clostridium botulinum* type E spores in fish end-products. Presence of carrion has also been shown as a factor increasing risk of fish botulism. Good aquaculture practices (GAP) can reduce spore prevalence in fish and some of the pre-harvest risk reduction measures implemented are removing bottom sludge, proper cleaning and disinfection of ponds, good hygienic condition of feed (trash fish) used in fish feeding, and the daily removal of weak, damaged or dead individuals.

The location of the farm and possible contamination with faecal pollutants (run-off waters, human sewage and farm effluents, wild animals) should be addressed, as sources of faecal contamination (animal/human) can occur accidentally in the vicinity of the farm (Pullela *et al*., 1998). This will increase the prevalence of pathogens (*Salmonella*, *Shigella*, pathogenic

Escherichia coli, enteric viruses, hepatitis viruses, parasites) (WHO, 2006). Monitoring of harvest areas for faecal pollution and microbiological analysis of products can address these safety issues. Introduction of aquatic species in new habitats for recreation or aquaculture can change parasite and bacteria prevalences.

4. Consideration of the relevance of on-farm pre-harvest welfare factors in aquaculture (dealt with by AHAW Panel) for the safety of fish products.

4.1. Water quality and environmental conditions

Chemicals that induce stress if outside of optimal range are dissolved ions (sodium, chloride, calcium, and bicarbonate), pH, and dissolved oxygen. Other group consists of chemicals that, in excess, compromise welfare and, at the same time, are potentially harmful to the fish. They are contaminant toxicants, such as heavy metals, pesticides, and supersaturated gases; and natural (result of metabolic activity) substances, such as ammonia, nitrites, carbon dioxide, hydrogen sulphide, suspended solids, phytoplankton, and other metabolic wastes.

Adequate water quality is a necessary condition to maintain the well-being and health of farmed fish. Fish are in intimate contact with their environment through the huge surface area of their gills, so they are vulnerable to poor water quality and water borne pollutants. Changes in the environmental conditions trigger in the fish adaptive neuroendocrine modifications (triggering blood sugar increase), also known as stress response. By this, fish is better able to overcome the challenge. When the fish is kept long enough in conditions beyond its normal level of tolerance, its well-being is adversely affected and the animal is unable to maintain a normal physiologic condition. The response to these stressors is hormone disbalance, osmoregulation disruption (which can lead to dehydration or over-hydration), suppression of the inflammatory response (immunosuppression), and as a result the fish is more susceptible to disease and possibly prone to pathogen carriage and this may have an effect in the safety of fish products. Other consequences are reduced growth and reproductive dysfunction.

4.2. Other stressors

A number of biological stressors have been recognized in the pre-harvest stage such as stocking density, grading, mixing of species, presence of predators, handling, transport, and removal of fish from water. The most important physical stressors are temperature and light. Temperature of the source water is very important in the selection of production sites. Species-specific temperature requirements also make certain climates and water sources preferred for optimal growth. Only for some species which are grown in tanks, water temperature control is possible. Rapid water temperature changes will also cause stress in fish. It is generally recommended to change the water temperature slowly at a rate of less than 3^{o} C per hour. This allows the fish to adapt to a new water quality condition. Inadequate light regimes (unnatural seasonal or daily patterns of light intensity, light-dark regimes) can be a cause of stress.

As before, the response to these stressors is hormone disbalance, osmoregulation disruption, suppression of the inflammatory response (immunosuppression), and as a result the fish is more susceptible to disease and possibly prone to bacterial carriage and this may have an effect in the safety of fish products.

4.3. Antimicrobial usage

A careful and judicious utilization of antimicrobials is pertinent for the treatment of bacterial infections in fish; therefore they play a major role in fish health and welfare. On the other hand, its indiscriminate usage can facilitate the emergence of antimicrobial resistance. Thus a responsible use in fish production is essential, and complementary to good management, biosecurity, vaccination, disease surveillance, optimal nutrition and farm hygiene. Other strategies to reduce antibiotic use in farmed fish such as improving disease immunity (feed-based immunostimulants) can be considered. For some fish diseases, use of antimicrobials is advantageously substituted by vaccination. According to FAO/OIE/WHO (2006), use of antimicrobials for disease prevention can only be justified where it can be shown that a particular disease is present on the premises or is likely to occur. The routine prophylactic use of antimicrobials should never be a substitute for good animal health management.

4.4. Vaccination

Vaccination programs have contributed significantly to reduce the losses due to disease outbreaks in fish farming, and represent in addition the major factor for the enormous reduction in antibiotic usage in some types of aquaculture experienced in recent years (FAO/OIE/WHO, 2006). There are three major modes for the application of vaccines: oral, immersion and injection. Vaccination, and especially intra-peritoneal vaccination with oil adjuvant vaccines, may generate severe side-effects affecting fish welfare (inflammation, tissue adhesions around the injection site, abscesses, pigmentation, granulomata, loss of appetite). Besides, handling involving injection vaccination can be also a stress factor for fish.

4.5. Feeding

Inappropriate feeding and nutrition has been referred to as a cause of stress. One possible cause is the use of improper feeding rate (either over-feeding or under-feeding/starving the fish should be avoided during the ongrowing stage). Over-feeding, especially where demand feeders are in use, is a significant welfare issue because of the effect that wasted food disintegrating into the water column can have on the oxygen levels and water quality. Use of mechanical feeders correctly loaded and programmed for the biomass of fish avoids this risk. Insufficient feeding or the spread of feed limited to small spots can enhance competition and hence aggression. Feed should also have the appropriate quality to meet the nutritional requirements of the species farmed.

4.6. Farm system and location

The type of production system in which fish are grown is an essential factor that influence health, welfare and to some extent, safety of the final product. It encompasses many other factors (stocking density, diet, feeding technique, water quality, management procedures, vaccination programs, waste removal, harvesting and slaughtering techniques, etc). Intensive systems give producers a better chance to manage biological risks by using water quality control, feed management, biosecurity, vaccination, etc. On the other hand, some stressors (crowding, handling) occur more commonly in intensive systems and if not properly managed, they may increase the risk of pathogen carriage and/or disease. For example, in intensive systems with low water renewal and oxygen added, carbon dioxide produced by fish respiration can significantly reduce water pH if not enough water renewal is accomplished. In intensive systems the fish density is high, and complex management systems are needed. In relation to the farm system, design and layout of sites has also influence on welfare, and for example netting in cages should be smooth and non-abrasive to prevent body lesions or the design and layout in the case of ponds or raceways. Other aspects in the selection of sites for farms consider the soil characteristics, and environmental considerations (discharges). Biosecurity measures, hygiene and sanitation procedures should be implemented including the control of animal vectors, quarantine step for all new fish, immediate removing of dead fish, appropriate cleaning of sediments and disinfection of tanks and equipment.

On the other side, extensive systems have a lower degree of intensification and avoid excessive handling, crowding, and therefore are in principle less stressful. Because control is not fully exerted over many factors (related to feeding, water quality and fish health) there are more opportunities for bacterial carriage and disease. In extensive systems there are some specific stressing factors such as the presence of predators, which are less easily controlled. Measures intended to preserve fish welfare by avoiding stress or improving environmental conditions will normally have a positive impact on the safety of the food product.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

1. For the species considered in the report, fish farmed in Europe have a good record of safety with respect to biological hazards. This conclusion is based on scientific publications (WHO, 1999; Hastein et al., 2006), and on the absence of reports linking fish-borne bacterial or parasitic diseases with the consumption of finfish aquaculture products in Europe. The risk associated with aquaculture products is frequently very low due to: (i) low occurrence of pathogens in the production systems and practices in place, (ii) the implementation of risk management measures not only at pre-harvest stages but also during harvesting and processing, and (iii) the hygienic preparation of foods before consumption.
2. Scientific information available on on-farm practices affecting welfare, and that could compromise fish safety, is very limited. Present data do not enable a quantitative assessment of the food safety risks associated with on-farm welfare factors to be made.
3. Use of production procedures based on good aquaculture practices (as recommended in different industry’s codes of practice), that result in the provision of optimal animal welfare conditions, increases fish resistance to infections and therefore can lead to a reduction of the food safety risks associated with the resulting products. Measures intended to preserve fish welfare by avoiding stress or improving environmental conditions are expected to have a positive impact on the safety of the food product.
4. There are pre-harvest environmental and hygienic conditions (related to water temperature, salinity, chemicals, organic matter, oxygen levels, etc.), and practices (inadequate feeding or antimicrobial usage) which could increase the prevalence of certain microbiological hazards at farm level, and which also may have an effect on fish welfare and physiological condition (stress). Both these aspects impact on fish health, and subsequently may influence the safety of the end product.
5. Some aquaculture practices and conditions inherent to specific production methods may influence the safety of the food product. Intensive systems give producers a better opportunity to manage biological risks by using water and feed quality control, biosecurity, health management, and vaccination. On the other hand, some conditions (mostly associated with handling and crowding) occur more commonly in intensive systems and, if not properly managed, they may act as stressors, increasing the risk of pathogen carriage and disease.

6. Extensive systems have a lower degree of intensification and avoid excessive handling, crowding, and therefore are in principle less stressful. On the other hand, and when control can not be fully exerted over risk factors (such as non optimal feeding, poor water quality and poor fish health), there are more opportunities for pathogen carriage and disease.
7. Pre-harvest measures are to be complemented by the post-harvest best practices.

RECOMMENDATIONS

1. Further research on the quantitative relationship between on-farm factors consequentially affecting fish welfare, on one hand, and any food safety hazards associated with the resulting food product, on the other, should be encouraged in order to facilitate and improve quantitative risk assessment in the context of the food chain.
2. Extension of coordinated animal welfare / food safety research programs, should be encouraged and supported so as to improve the desired synergism between the two approaches.
3. Most factors that positively affect fish welfare also contribute to food safety. Where factors promote animal welfare but increase food safety risks, additional risk reduction measures should be implemented.

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