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Salmonella in fish feed; occurrence and implications for fish and human health in Norway

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Abstract

Globally, *Salmonella* is one of the most important food borne zoonotic pathogens. Norway has a favourable situation regarding *Salmonella*, as these bacteria are virtually absent in food producing animals and domestically produced food, including products from fish. Consequently, Norway has a low incidence of domestically acquired salmonellosis in the human population. Some *Salmonella* serovars can however occasionally be found in animal feed and its ingredients, as well as in the feed production facilities. During the years from 2000 to 2004, the prevalence of *Salmonella* in samples of feed materials varied from 0.14 to 0.33%. Of environmental samples obtained at Norwegian fish feed production facilities, 3.78% of the examined samples were positive. During the same period, the prevalence of *Salmonella* in Norwegian ready to use compound fish feed were shown to be 0.3%. The predominant serovars found in fish meal were *S.* Senftenberg and *S.* Montevideo. The same serovars were dominating in isolates from the production environment, and could in these cases be considered "house strains". In ready to use compound fish feed, the most common serovars were found to be *S.* Senftenberg, *S.* Agona, *S.* Montevideo and *S.* Kentucky. Under natural rearing conditions for farmed Atlantic salmon in Norway, and with low concentrations of *Salmonella* in the feed, the risk of transmission to humans via fish products is minimal. Epidemiological data on salmonellosis from the Norwegian Surveillance System for Communicable Diseases, show that the most common serovars in fish feed ingredients, fish feed and fish feed factories accounts for approximately 2 % of clinical *Salmonella* isolates from domestically acquired cases in Norway. There is no evidence for transmission of *Salmonella* from fish feed to humans. However, there is little information on the risk of *Salmonella* cross-contamination from fish feed, the ingredients and the factories to other parts of society, including wildlife. A probable cross-contamination between fish feed factories and seagulls have been described. The prevalence of antimicrobial resistant *Salmonella* strains isolated from fish feed, its ingredients and the production environment have so far been very low.

Keywords: *Salmonella*; Fish feed; Feed ingredients; Fish disease; Human disease; Environmental dissemination; Antimicrobial resistance

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Contents

1. Introduction

The salmonellae are Gram-negative, flagellated and facultative anaerobe bacteria. The taxonomy of *Salmonella* is rather complicated, and has been a subject of scientific debate for many years (Bell and Kyriakides, 2002). Detailed phylogenetic analyses by multilocus enzyme electrophoresis and DNA sequencing have demonstrated that the genus *Salmonella* includes the two species *Salmonella bongori* and *Salmonella enterica*. *S. enterica* may further be divided into seven distinct groups or subspecies, i.e. *enterica* (I), *salamae* (II), *arizonae* (IIIa), *diarizonae* (IIIb), *indica* (VI), and the diphasic groups IV and VII (Boyd et al., 1996). In addition, differences in lipo-polysaccharide and flagellar structure generate the antigenic variation that is reflected in the more than 2500 serovars so far described. The serovars of importance for fish feeds and their ingredients predominantly belongs to the species *S. enterica* subspecies *enterica*.

Around 700 000 metric tons of fish feed is produced annually in Norway. Since the feed conversion factor for coldwater fish is approximately 1, this amount is sufficient for the production of around 700 000 metric tons of farmed fish. Fish feed is largely based on the marine ingredients fish oil and fish meal. In addition, about 15% of the diet is wheat or other starch-rich ingredients. A recent development, to reduce feed cost and improve fish farming sustainability, is the partial replacement of marine ingredients with vegetable ingredients. Thus, fish feeds may contain up to 30% vegetable proteinous ingredients, such as wheat gluten, soybean meal or rapeseed meal. The major component in fish feed is still fish meal and fish oil, constituting between 60 and 80% of the diet. A typical salmon diet contains between 30 and 40% oil and between 30 and 40% proteins. In addition, it may contain up to 10% starch, and the water content is usually below 10%.

Even though *Salmonella* is not a spore former, heat-treated products may be contaminated by this bacterium. Internationally, fish meal, meat and bone meal, maize and soy products have been shown to have a relatively high prevalence of *Salmonella* (Veldman et al., 1995; Jones and Richardson, 2004). Thus, fish feed are shown to occasionally harbour *Salmonella* originating from ingredients or the processing environment. This article discusses the prevalence of *Salmonella* in Norwegian fish feed, its ingredients and production facilities for fish feed. Furthermore, the implications for fish and human health of such *Salmonella* contamination are assessed.

2. Growth and heat resistance of *Salmonella* in feed materials

Bacteria in the genus *Salmonella* are considered typical intestinal organisms, being able to colonize the gastrointestinal tract of animals and humans. However, the ability of *Salmonella* spp. to survive and multiply in environments other than the intestine, e.g. food and feed, is well documented (D'Aoust et al., 1997). In the production environment, *Salmonella* tends to form biofilms on both inert and organic surfaces. In this state, bacteria are better protected against environmental stresses (Costerton et al., 1999; Donlan and Costerton, 2002). The bacterium may grow at water activities (a_w) above 0.94 (Bell and Kyriakides, 2002). As is the case for heat resistance, the survival of *Salmonella* spp. in stored food and feeds is enhanced by a lowered a_w (Grau, 1989). It is known that the ability of *Salmonella* strains to survive air drying varies considerably (Humphrey et al., 1995; Jørgensen et al., 2000),