Dietary supplementation of histidine diminishes cataract incidence in Atlantic salmon

Andreas Brezas
CJ Europe

Abstract

Disease outbreaks are a major threat and constrain the sustainable growth of the aquaculture sector. Cataract is an eye disorder which is affecting heavily the farmed Atlantic salmon since the 1990s. The etiology of the cataract disease has been found to be linked to histidine deficiency during critical fish life periods in intensive farming. N (alpha)-acetylhistidine is a crucial metabolite of histidine found in the fish eye lens, which has been shown to have important roles as a critical biomolecule for the maintenance of the lens water balance and cell integrity. Conclusively, it has been shown that dietary histidine supplementation higher than 1.4% of diet is required to mitigate the development of cataracts in Atlantic salmon and promote fish welfare and ultimately salmon farming sustainability.

Background

Atlantic salmon (Salmo salar) is considered to be the most successful aquaculture species globally, showing higher production growth rates compared to the aquaculture sector per se (Kobayashi et al., 2015). Salmon aquaculture industry was established in the early 80s, since then it has been rapidly expanded, from 230 thousand metric tons (MT) in 1990 to 2.2 million MT in 2018 (Iversen et al., 2020). In aquaculture, disease prevalence and impacts often have major cost consequences. Cataract is considered as one of the most important diseases in the farming of Atlantic salmon. In addition to the economic implications, the production of fish with visual disturbance raises important welfare concerns. Since the mid-1990s, the salmon aquaculture in Europe as well as in Canada and Latin America has suffered from severe occurrences of irreversible cataracts (Bjerkås et al., 2004). Cataract is a common eye disorder causing the fish eye lens to become opaque (Fig. 1), resulting in reduced vision. Cataracts can lead to impaired vision or blindness which can impact avoidance behavior and also feeding ability, as Atlantic salmon is a visual predator and can have problems locating pellets which leads to reduced feed intake, growth and increases the susceptibility to secondary diseases and mortalities as compared to healthy fish. Cataract prevalence in farmed Atlantic salmon has been related mainly to histidine deficiency in salmon feed (Bjerkås et al., 2004). This article aims to highlight the importance of dietary histidine supplementation for preventing/alleviating the occurrence of cataracts in Atlantic salmon.

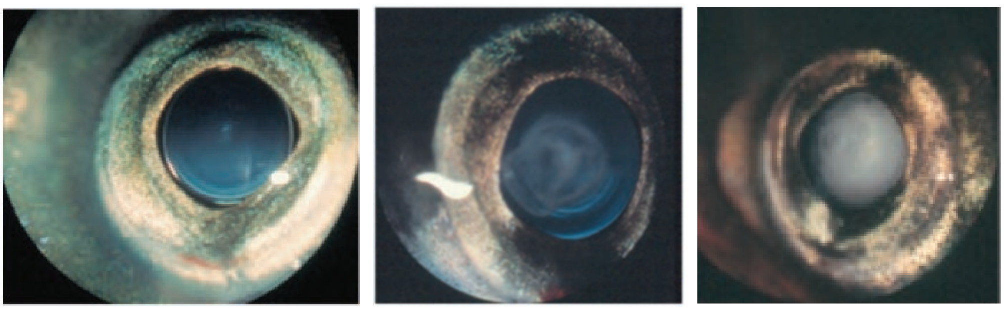

Figure 1. Eye cornea showing different degrees of cataract severity (adapted from Bjerkas et al., 2004)

Dietary histidine mitigates the incident of cataract in adult Atlantic salmon

In recent years, several factors have been linked to the development of cataracts, such as nutritional deficiencies, genetic predisposition, rapid growth, osmotic imbalance, oxidative stress, water temperature fluctuations, and the change in water salinity (Iwata et al., 1987; Hargis, 1991; Bjerkås et al., 1996; Wall, 1998; Bjerkås et al., 1998; Breck and Sveier, 2001). Nevertheless, the dietary supplementation of histidine was found to be the main factor in preventing cataracts in Atlantic salmon (Moro et al., 2020). This important physiological role of histidine was discovered after an outbreak of cataracts in rapidly growing Atlantic salmon when fed with diet deprived of blood meal (the richest source of histidine among common feed ingredients) due to the EU ban on processed animal protein in 1990s. Waagbø et al. (2010) examined the impact of different dietary histidine levels and seasonality on cataract severity. The authors concluded that severe cataractogenesis was occurred between July and September and the severity of disease was mitigated by the elevated dietary histidine content. The above study showed that the histidine supplementation at the early stage of cataractogenesis could impede the development of cataract in Atlantic salmon.
In another study, Remø et al. (2014) fed salmon smolts with different levels of histidine (10, 12, 14, 16, and 18 g/kg of diet) for a period of 13 weeks and observed a positive correlation between lens N (alpha)-acetylhistidine concentrations (a histidine metabolite) and dietary histidine intake. Interestingly, they also observed that cataract prevalence and severity were strongly and negatively correlated (r = -0.76) with the dietary histidine concentration (Fig. 2). The authors concluded that the required amount of dietary histidine that minimized the risk of cataract development is 14.4 g/kg of diet. Similar findings were reported by Sambraus et al. (2017), who observed that the severity of cataract formation in diploid and triploid Atlantic salmon smolts was reduced when the fish fed a diet with high histidine content (1.31%) compared to fish fed a diet with low histidine content (1.04%).

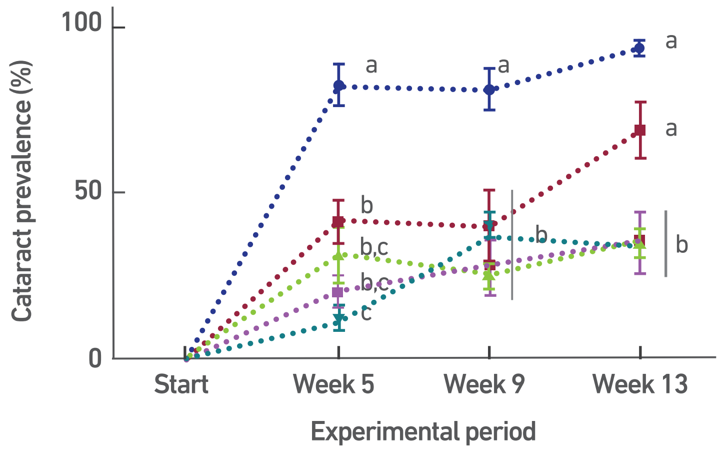

Figure 2.Cataract prevalence during 13-week feeding trial (10, 12, 14, 16 and 18g His/kg feed) (adapted from Remø et al., 2014)

Role of N (alpha)-acetylhistidine in preventing cataract in Atlantic salmon

N (alpha)-acetylhistidine (NAH) is a biomolecule present in the fish eye lens. Rhodes et al. (2010) observed that NAH levels in the lens of salmon in seawater are much higher as compared to salmon raised in freshwater. The lens NAH has been shown to have important roles as an osmolyte, buffer component, and possibly intracellular antioxidant and is therefore essential towards the maintenance of the lens water balance and cell integrity (Baslow, 1998; Breck et al., 2005; Rhodes et al., 2010; Remø et al., 2011).
Tröße et al. (2009), also confirmed previous evidence that lens NAH contents reflect the dietary histidine levels. In more detail, they found that NAH contents were negatively correlated to cataract scores in adult Atlantic salmon fed three different amounts of dietary histidine (9, 13, and 17 g/kg diet) for four months (Fig. 3).

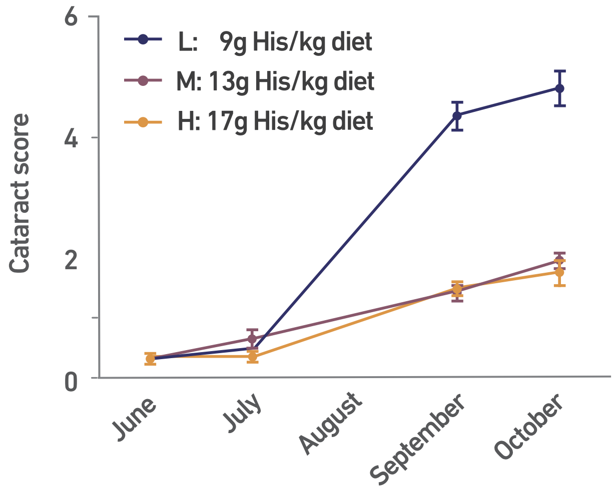

Figure 3. Cataract scores of salmon fed with different dietary histidine levels throughout the experimental period (adapted from Tröße et al., 2009)

Their findings were further corroborated by Waagbø et al. (2010) who also found a negative correlation between individual lens NAH and cataract score in adult Atlantic salmon fed experimental diets supplemented with different histidine levels (Fig. 4).

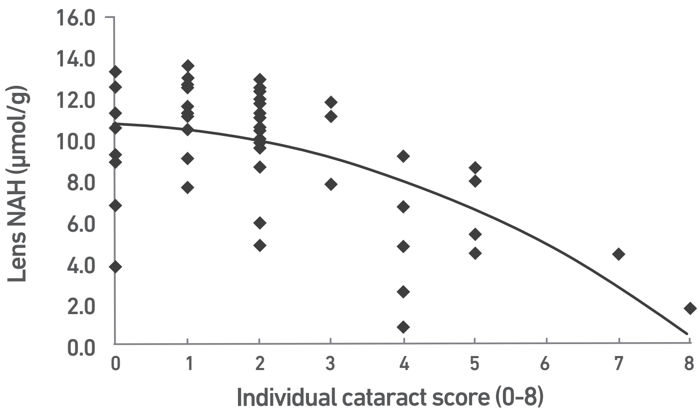

Figure 4. Correlation between individual lens N-acetyl-histidine (NAH) and cataract score in adult Atlantic salmon fed experimental diets differing in histidine content (adapted from Waagbø et al., 2010)

Conclusions

It is well established that the dietary supplementation of histidine can prominently protect Atlantic salmon against cataract development by both securing the cells from oxidative stress and maintaining the water balance in the lens. The aforementioned studies clearly supported that the metabolic requirement for histidine for optimal ocular health and wellbeing are much higher (>1.4% of diet) as compared to the ones established for maximum growth (0.8% of diet) in fast-growing Atlantic salmon.

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