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Viability of tallow inclusion in Atlantic salmon diet, as assessed by an on-farm grow out trial

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ABSTRACT

The results of a recent increase in research interest directed at the inclusion of tallow in fish feed formulations are suggesting tallow is viable as a potential substitute for other alternative lipid sources such as poultry by-product oil. Although strong growth performance data has been shown, reservations still exist regarding reduced digestibility and the potential impacts this could have on performance over the duration of a grow-out period in low temperature conditions. Also little information is yet available on the potential effect of dietary tallow inclusion on final product quality. A large scale farm based study testing the inclusion of tallow at 40% inclusion, partially replacing poultry by-product oil, in commercial diets of Atlantic salmon over a winter grow-out period in southern Tasmania, Australia was conducted. Tallow inclusion had no impact on growth performance or nutrient digestibility. Tallow resulted in a slight improvement in fillet quality exhibiting a significant reduction in n − 6 PUFA and the n6:n3 ratio, and an increased n − 3LC-PUFA tissue deposition. Consumers were unable to display any preference in liking between 3 salmon products (cold smoked, hot smoked, and cooked) as a result of tallow inclusion. This study demonstrates the viability of partial inclusion of tallow in Atlantic salmon diets over a winter grow-out period.

Statement of relevance

Improved knowledge of alternative dietary energy sources (oils and fats) to be used in aquafeed, (replacing the increasingly expensive, and diminishingly available, fish oil) is a key area of research towards improved environmental sustainability and economic viability of the aquaculture sector. Following a promising laboratory based, research scale, in vivo trial aimed at assessing the viability of tallow in salmon feed, a larger and longer duration farm-based trial was implemented to validate initial findings. Consumer test of final products (fresh–cooked, hot smoked and cold smoked fillets) showed no modification of sensorial attributes. Tallow is hereto shown to be a highly viable alternative oil for the salmon aquafeed industry.

1. Introduction

Sustainability and availability issues, and the resulting economic constraints surrounding the use of aquaculture's preferred lipid source fish oil, have resulted in a considerable reduction of its inclusion level in commercial aquafeed (from 100% in the late '90s, to 10–35% of total added lipid nowadays; Tacon and Metian, 2008; Tacon and Metian, 2015). Thus, high inclusion levels of 'alternative' lipid sources in aquafeed for commercially reared seafood are now an accepted and common practise globally (Pickova and Morkore, 2007; Torrissen et al., 2011). The ever increasing growth of aquaculture production to meet global seafood demand and the rise of 'more sustainable' and 'more economically viable' alternative oils in aquafeed means that aquaculture is now not just a major consumer of fish oil but also of terrestrially produced vegetable oils and animal fats (Troell et al., 2014). This places aquafeed manufacturers in direct competition for resources with other major oil users such as the food, feedstock and biodiesel industries, and the more specialised nutraceutical and cosmetics sectors. Furthermore, aquaculture's requirement for high quantity and high quality lipids means that these resources come at a substantial expense to the manufacturer and are influenced by, and susceptible to, often unpredictable market forces. Pressure to reduce the cost of aquafeed means that manufactures are now looking for more cost effective alternative lipid sources (Naylor et al., 2009). Consequently, considerable research effort is being directed towards the assessment of various alternative lipid sources on the performance and final product quality of numerous commercial aquaculture species (Turchini et al., 2009; Morais et al., 2012; Benítez-Dorta et al., 2013; Eroldogan et al., 2013; Castro et al., 2015).

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Salmonid aquaculture is well known to be one of the largest consumers of fish oil and to increasingly require and include additional alternative lipid sources; much research has been focussed in this area (Bell et al., 2004; Bureau et al., 2002; Codabaccus et al., 2012; Hardy et al., 1987; Menoyo et al., 2003; Torstensen et al., 2004a; Greene and Selivonchick, 1990; Zheng et al., 2004). The type of lipid source used in aquafeed can have important implications, impacting on nutrient digestibility, growth performance and the nutritional quality of the fillet (Turchini et al., 2009), and accordingly the mitigation of these impacts is a major goal of research focusing on alternative lipid in aquafeed. In Europe, vegetable oils, such as canola (rapeseed) oil, are the primary alternative sources used in aquafeed. In North and South America and in Oceania rendered animal fats are commonly used (Turchini et al., 2010), with the most frequently utilised alternative lipid source of animal origin being poultry by-product oil (PbO; Bureau and Meeker, 2010). PbO is regarded as a good alternative lipid source, proven to produce good growth performance, high feed palatability and nutrient digestibility with a final product of acceptable quality (Bowyer et al., 2012; Hatlen et al., 2013; Liu et al., 2004; Rosenlund et al., 2001; Turchini et al., 2013; Liland et al., 2014; Parés-Sierra et al., 2014). However with the steadily increasing demand for this resource, including the rapidly expanding pet food industry, its availability is diminishing and as a result its price is increasing. With demand only expected to increase, further shortages and price hikes are expected and this is forcing aquafeed manufactures to evaluate the potential of further alternatives to PbO.

One lipid source that stands out as a possible substitute for PbO is tallow (TAL; rendered beef and/or lamb fat). TAL is abundantly produced globally, its usage is not considered to be directly competing with the food and terrestrial animal feed sectors, and has been identified by researchers as having strong potential for inclusion in aquafeed, with considerable and promising research effort having recently been focused on assessing its viability (Bureau et al., 2008; Gause and Trushenski, 2013; Guderley et al., 2008; Hardy et al., 1987; Xue et al., 2006; Emery et al., 2014; Woitel et al., 2014). Despite strong growth performance data, concerns still exist regarding the viability of TAL due to studies recording reduced digestibility resulting from its inclusion (Emery et al., 2014; Bureau and Meeker, 2010; Trushenski and Lochmann, 2009). TAL contains a high saturated fatty acids (SFA) content relative to many alternative lipid sources and it is well demonstrated that this can have a negative impact in reducing lipid digestibility (Bureau and Meeker, 2010), with impacts further exacerbated by reductions in water temperature (Cho and Kaushik, 1990; Hua and Bureau, 2009; Ng et al., 2007).

Nevertheless, despite its higher level of SFA in comparison to other commonly used alternative oils, TAL has some unique advantages: it contains a relatively balanced level of SFA and monounsaturated fatty acids (MUFA) and extremely low omega−6 polyunsaturated fatty acids (n−6 PUFA) compared with other commonly used alternative lipid sources, including PbO. Fish consumption is recommended as a rich source of the health promoting omega−3 long-chain polyunsaturated fatty acids (n−3 LC-PUFA) eicosapentaenoic acid (EPA; 20:5n−3) and docosahexaenoic acid (DHA, 22:6n−3). Increased fish consumption is also advocated in order to improve the overall omega−6 to omega−3 ratio (n−6: n−3) consumed (Simopoulos, 2008; Simopoulos, 2011; Lands, 2014). Fillet fatty acid composition closely reflects that of the diet (Turchini et al., 2009; Torstensen et al., 2004b; Bell et al., 2002; Woitel et al., 2014), consequently, though n−3 LC PUFA content is only minimally affected by the type of lipid source substituted, linoleic acid (18:2n−6) competes with n−3 LC PUFA for deposition (Trushenski et al., 2008; Trushenski and Kanczuzewski, 2013; Woitel et al., 2014) and is readily incorporated into the fillet (Turchini et al., 2013; Rosenlund et al., 2001; Bell et al., 2001) detrimentally effecting the quality by increasing the n−6: n−3 (Pickova and Morkore, 2007; Rosenlund et al., 2011). Substitution with TAL improves fillet n−6:n−3 and n−3 LC PUFA deposition efficiency (Emery et al., 2014; Trushenski et al., 2011; Greene and Selivonchick, 1990; Xue et al., 2006), relative to n−6 PUFA rich lipid sources (Woitel et al., 2014; Emery et al., 2014).

Following our recent demonstration of the viability of PbO substitution with TAL in feed for juvenile Atlantic salmon (*Salmo salar*) reared at low temperature in an indoor experimental facility (Emery et al., 2014), the aim of the present study was to directly address the viability of TAL dietary inclusion at a commercial scale. Accordingly, this study was conducted on farm, over the winter grow-out period in southern Tasmania, monitoring growth performance, nutrient digestibility, fatty acid composition and metabolism as well as sensorial quality (consumer preference) of final products. The winter grow-out period was chosen to emphasise the potential negative impacts of low water temperature.

2. Methods

2.1. Location, animals, experimental design and sampling

The trial was conducted over the winter grow out period (195 days, 28 weeks) from April 19, 2013 to October 31, 2013 in the Hideaway bay, Dover, Tasmania (Huon Tasmania, Hideaway bay site; 43°15′ 52.2″S 147°04′37.7″E). Immediately preceding the allocation of the trial an initial sample of 10 fish were randomly selected from the trial cohort, euthanized in excess anaesthetic (AQUI-S, 0.5 ml/L) and stored at −20 °C until subsequent analysis. 1800 Atlantic salmon (average initial weight 1.7 kg) were then randomly distributed between six floating sea pens (5 m×5 m×5 m, 300 fish per pen). Each of the pens was then randomly assigned one of 2 dietary treatments in triplicate (3 pens per treatment; $n = 3$, $N = 6$). Fish were fed with one of the two experimental diets using a Sterner feeder with 40 L hopper and spinner feed spreading mechanism dispersing feed over ~80% of the cage surface. Feeding sessions were controlled by an automated AQ1 feed system twice daily to satiation at dawn and dusk. Feeding was programmed to commence 15 min before sunrise for the dawn session and 15 min after sunset for the dusk session. For each feeding session fish were fed 20 min to satiation followed by a 10 min break and then fed for a further 20 min to satiation. A 0.5 m diameter, 0.5 m deep cone was positioned at a depth of 4 m channelling any uneaten feed through an infrared sensor. Satiation was determined by detection of pellets through the sensor which automatically turned the feeder off. All feeding sessions were overseen by an observer to ensure the operation of all systems were correct and consistent. Feed consumption and mortalities were recorded throughout the duration of the trial. Water temperature (average: 12.7 °C) and dissolved oxygen levels (average: 7.8 mg/l) were tracked over the duration of the trial and remained within acceptable limits, salinity for this site was 34 ppt.

During the last week of feeding ten fish were randomly selected from each pen and anaesthetised for faecal collection, faeces were collected by hand stripping and samples were used for subsequent digestibility estimation. At the completion of the grow-out phase, all fish were anaesthetised and weighed, and 42 fish from each treatment (14 fish per pen) were randomly selected and separated, these fish were randomly allocated into 3 groups: the first group (4 fish) was used to measure biometry and for the chemical analysis of fillet, the second group (4 fish) were used for chemical analysis of the whole body and the third group (6 fish) were used for sensory analysis by means of a panel taste test. These separated fish were immediately placed in an ice slurry, following this the fish used for chemical analysis were frozen to −20 °C and stored until subsequent analysis. Fish that were used for the panel taste test were taken from the slurry to be processed by Huon Aquaculture Company, Tasmania. These fish were further subdivided in three sub-groups and went through standard commercial procedures of processing for three different preparations: hot smoke, cold smoked and fresh fillet.