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ECO-FORMULATION OF FISH FEEDS: A PROMISING EFFICIENT SOLUTION TO LIMIT AQUACULTURE IMPACTS ON THE ENVIRONNEMENT

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Context:

Aquaculture has been the main source of fish for human consumption since 2015. In 2018, it provided 53% of consumed fish, a percentage that is expected to increase over the long term as part of the solution to provide sufficient food and protein to more than nine billion people by 2050. Nevertheless, this expansion is not free of environmental impacts (Bohnes et al., 2019). Thus, a major challenge for aquaculture is to find new practices to make its development more environmentally friendly. One solution to limit these impacts is to use feed as a lever because it contributes the most to the impacts of fish production (Boissy et al., 2011). Aquaculture is also criticised for its heavy dependence on limited resources due to its massive use of fishmeal and fish oil. Multiobjective (MO) formulation, which aims for a compromise between lower cost and lower environmental impacts, appears to be a promising solution to reduce the environmental footprint of aquaculture production (Garcia-Launay et al., 2018). However, carnivorous fish, such as salmonids, are considered to be very sensitive to the composition of their diet, as illustrated by the negative impact of replacing fishmeal and fish oil with plants on growth (Lazzarotto et al., 2018). The objectives of this study were to design an eco-friendly trout feed (ECO-diet) using MO formulation and to compare its zootechnical and environmental performances to those of a commercial feed (C-diet) containing 16% fishmeal and 6.5% fish oil.

Material and methods:

Two isoprotein, isolipid and isoenergetic diets were formulated: a control diet (C-diet) and an ECO-diet, formulated using a multiobjective function adapted from Garcia-Launay et al. (2018) to minimize both the environmental footprint (climate change, non-renewable energy demand, acidification, NPPU, land occupation, eutrophication, water dependence, phosphorus demand), and price of feed. The digestibility of the diet was measured and a 12 weeks-growth trial was conducted (3 tanks per diet) on juvenile rainbow trout (initial body weight of 61 g ±1.4 g) to assess the consequences of these diets on growth performance, body composition and nutrient utilization. The experimental results were used in a LCA approach to estimate the environmental impacts of the diet and of 1 kg of body-weight gain at rearing facility scale. Emissions and impacts were calculated using SimaPro® software v8.3.0.0, with the attributional databases ecoinvent® v3 and AGRIBALYSE® including the ECOALIM dataset (Wilfart et al., 2016) for background data. Environmental impacts categories were those described by Wilfart et al. (2016) associated to NPPU and water dependence from Boissy et al. 2011 which are specific to aquaculture systems. Statistical analyses were performed using R software (v4.01). Results were expressed as mean ± 1 standard deviation. The normality of the residuals and homogeneity of the variances were checked using a Shapiro-Wilk test and Bartlett test, respectively. Then, data were tested by one-factor analysis of variance (ANOVA) to measure effects of diets on growth-performance and body-composition

parameters, and environmental impacts per kg of body weight gain. A Kruskal-Wallis test was applied to non-normal data. When a significant difference was observed, Tukey's range test was applied to compare least-square means. For all statistical analyses, the significance level was set at 0.05.
A mixed linear regression model with the tank as the random effect was used to determine effects of the diet, duration of the experiment, and their interaction on trout growth using the lmer function of the lme4 package of R.

Results and discussion:

MO formulation changed the composition of the diet greatly, which has decreased environmental impacts of the feed. It increased the number of ingredients used (from 16 to 23) but reduced the use of fishmeal and fish oil by half. MO formulation also led to the elimination of soy products, faba bean, and gluten meal in favor of processed animal co-products that have high protein contents and low climate change impact. Rapeseed oil also disappeared from the ECO-diet due to its major contribution to land use, eutrophication, and acidification and, to a lower extent, climate change (Figure 1). Unlike other studies, in which MO formulation was applied to pig and poultry feeds (Meda et al., 2021), the ECO-diet was less expensive than the commercial-type C-diet (-8%). Indeed, the C-diet was formulated as closely as possible according to current commercial practices, which consider both least cost and pre-set percentages of fishmeal and fish oil. This approach increased costs. The still high content of fishmeal and fish oil in the C-diet thus explains why the C-diet cost more than the ECO-diet, which was formulated without constraints on these two raw ingredients.
The ECO-diet had high digestibility, which differed little from that of the C-diet. Mean fish body weight after 12 weeks of growth did not differ significantly from that obtained with the C-diet, but analysis of fish growth curves (Figure 2) indicated that the ECO-diet could lead to lower growth in the long term. Based on these growth curves, fish fed the C-diet would require 5 more days of rearing to reach the size of a human meal portion (250 g), while those fed the ECO-diet would require 20 more days. The decrease in growth performance in the long term is probably mainly related to the decrease in feed intake. The lower protein and fat digestibilities of the ECO-diet could have also contributed to the trend of lower growth but to lower extent compared to feed intake because nutrients digestibility could be considered as high in both diets. In any case, this decrease cannot be associated with a decrease in feed efficiency, because the feed conversion ratio did not differ between the two diets.

Overall, using MO formulation to decrease environmental impacts of feed made it possible to significantly decrease the environmental footprint of the fish farming system studied per kg of body weight gain (Figure 3). The decrease in impacts was lower at the farm level than that at the feed level, especially for EU and, to a lesser extent, NRE and CC. In contrast, the feed and farm levels had similar decreases for NPPU, WD, LO, AC, and PD. This is not in agreement with what has been observed in pig and poultry where the formulation has been applied (de Quelen et al., 2021; Meda et al., 2021). The farm level included emissions due to biological processes of fish as well as emissions from the operation of the farm facility. NPPU and PD depended only on the feed, which explains why their decrease was the same for both levels. In the experimental system used, the fish were reared in raceways in which water was taken from a river, continually flowed through the system, and then returned to the river. Because the water could thus be reused, it was not included in water use in life cycle inventory, as recommended by Boissy et al. (2011). Consequently, the decrease in WD at the farm level was the same as that at the feed level. Finally, the experiment was performed in 60 L tanks, which contributed less to LO than the areas used to produce the crops that provided feed ingredients.

Conclusion:

MO formulation is a useful tool to reduce the environmental footprint of aquaculture production without compromising animal performances or necessarily increasing production cost. Nevertheless, some points deserve further investigation. For example, because growth performance could decrease over the long term, the rearing period should be extended to validate the performance of these diets in portion-size trout or to evaluate them when producing large trout intended for smoked fillets, which requires longer rearing periods.

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