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ScienceDirect
Aquaculture 269 (2007) 220–231
Aquaculture
www.elsevier.com/locate/aqua-online

Response of a lean muscle and a fat muscle rainbow trout (*Oncorhynchus mykiss*) line on growth, nutrient utilization, body composition and carcass traits when fed two different diets

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Received 26 October 2006; received in revised form 21 February 2007; accepted 26 February 2007

Abstract

The objective of this study was to characterize the body composition, nutrient utilization, energy storage sites and major economic traits of trout selected at pan-size for or against body weight corrected muscle fat content (fat line, FL and lean line, LL respectively). The study focused on the effect of selection in fish size larger than the size where selection has been applied, and the possible effect of diet composition on the differences between lines. FL and LL trout were fed two diets differing for energy content and protein/lipid ratio during 62-days. The feeding trial (day 370 to day 432) started with 327g fish. Dietary protein and lipid contents were 58.7% and 8.3% dry matter (DM) respectively for diet D8 and 47.7% and 26.7% DM for diet D27. Growth, feed intake, feed utilization and traits related to body shape and composition were recorded. In both lines diet D27 improved growth rate, feed efficiency, protein retention and fat gain ($P<0.05$), and was associated with a higher viscero-somatic index, fillet fat content and lower trimmed fillet yield than diet D8. At the end of the trial, LL fish were slightly heavier than FL ones ($P=0.02$, no line × diet interaction). The main differences between lines were observed in lipid gain and retention. Values of lipid retention (% of intake) were higher in FL fish ($P=0.04$) regardless of diet, and suggested a greater ability of FL fish in *de novo* lipid synthesis. Fat deposition (% of weight gain) was greater in FL fish during the trial and occurred in fillet ($P=0.04$), on internal side of the belly flap ($P=0.04$), as well as in other sites of the body, as indicated by higher overall body lipid content at day 432 ($P=0.02$, no line × diet interaction). Nevertheless, carcass and fillet yields were not different between lines regardless of diet. In conclusion, selection for body weight corrected muscle fat content modified the ability of the fish to utilize nutrients and to store more or less fat in the different body sites. The differences were expressed in a large range of dietary protein/fat ratios. Line × diet interactions were recorded for a very limited number of traits, indicating that the combined use of genetic and nutritional tools should be efficient to manage carcass quality (growth, body shape, processing yields) and fat deposition (quantity and body location) in trout, with no need to adapt diet formulation according to lines.

Keywords: *Oncorhynchus mykiss*; Nutrition; Genetics; Muscle composition; Yields; Selective breeding

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doi:10.1016/j.aquaculture.2007.02.047

1. Introduction

Quality traits have become of considerable importance to the salmon industry. Condition factor contributes to the appearance of the fresh product ('normally' shaped fish, with intermediate values of condition factor being preferred), and to processing yields (Gjerde and Schaeffer, 1989; Rye and Gjerde, 1996; Morkore et al., 2001; Kause et al., 2003). Visceral and abdominal fat strongly contribute to the non-edible parts of the product ("wastes") that are detrimental to dressing yields and are disadvantageous in term of feed conversion efficiency (Gjerde and Schaeffer, 1989; Rye and Gjerde, 1996; Elvingson and Johansson, 1993). Because of a part–whole relationship, carcass yield is largely determined by the viscero-somatic index (ratio weight of viscera/total body weight). It is also expected to be positively correlated with belly thickness (Gjerde and Schaeffer, 1989; Neira et al., 2004). Fat deposition in the abdominal area of the belly wall and around fins increases the dress-out losses during fillet processing. Finally, the fillet fat content is a major component of color, texture and flavor of fresh as well as smoked products (Johansson et al., 2000; Morkore et al., 2001; Robb et al., 2002). Moisture content, inversely correlated to lipid content, is also an important feature when fillets processing includes smoking (Morkore et al., 2001). Yet, the 'optimum' level of lipid content in the fillet is somewhat debated, and has to be managed in a way that depends on several features like species, type of product (pan-size or large size), processing (fresh *vs*. smoked) and local market demand.

Fat content of farmed fish is generally regulated through feeding strategies. Many studies demonstrated that body fat level is highly affected by ration size and dietary energy supply. In salmonids, perivisceral adipose tissue and muscle are the major sites of fat storage. Fat content increases in both sites when fish are fed high energy diets (Corraze and Kaushik, 1999; Jobling, 2001). However, published data suggest that the capacity of rainbow trout (*Oncorhynchus mykiss*) to store lipid in white muscle is limited compared to Atlantic salmon (*Salmo salar*) (Einen and Skrede, 1998; Hemre and Sandnes, 1999; Rasmussen et al., 2000; Rasmussen, 2001). Restricted feeding or low fat diet can be applied as strategies for decreasing fish fat content but they impair growth, feed efficiency as well as fillet yields (Jobling et al., 1998; Rasmussen et al., 2000).

Genetic parameters indicate that the prospect of selecting for meat and viscera fat deposition is quite hopeful. Published values of heritability range from 0.2 to 0.3 for visceral fat and up to 0.5 for meat fat content (reviewed by Gjedrem, 1997). Estimates of genetic correlations suggest that selection may induce an opposite evolution of meat and visceral fat, contrarily to what happens under nutritional control of lipid content (Gjerde and Schaeffer, 1989; Rye and Gjerde, 1996; Kause et al., 2002).

Very little is known about the variation of diet utilization according to the genetic origin of fish. Studies have reported genetic variation for feed efficiency and a positive association with growth rate (Thodesen et al., 1999, 2001, in Atlantic salmon; Henryon et al., 2002, in rainbow trout), while comparison of fast and slow growing strains of rainbow trout or brown trout (*S. trutta*) did not show any difference (Valente et al., 1998; Mambrini et al., 2004a,b). In rainbow trout, family differences for growth according protein and carbohydrates diet content were recorded (Edwards et al., 1977; Austreng and Refstie, 1979; Refstie and Austreng, 1981; Blanc, 2002) but with no or limited interactions between family and diet composition.

We recently selected for or against body weight corrected muscle lipid content in two experimental lines of rainbow trout (lean and fat lines as described in Quillet et al., 2005). To our knowledge, this is the first example of a selection performed on traits related to lipid body sites in salmonids. Despite the short term selection history of these lines, they are a unique material to study the genetic × diet interactions in salmonids.

In a previous study performed at the size/age where selection was applied (portion-size 260 g fish), the two lines exhibited significant difference in fillet lipid content. Differences were also recorded for other traits including condition factor, belly wall thickness and internal fat coat of the belly increased in the fat line, but not for growth or major carcass components (Quillet et al., 2005).

The first objective of the present study was to analyze the same traits in larger size fish. The second objective was to investigate the difference between lines in nutrient utilization and ability in converting food energy content into body stores, to determine whether the selected trait and correlated responses varied in relation with fish size and/or with the diet, and whether the combination of nutritional and genetic factors could help in controlling major quality traits in rainbow trout. To meet these objectives, trout of the two lines were fed two diets that greatly differed in protein and fat contents. Major changes in energy and nutrient supply were expected to enhance differences between lines in food utilization and body stores. We hypothesized that a "restricted" level of dietary fat and energy would limit fat deposition differently between lines, and that high dietary protein level would promote protein growth