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Introduction

Rainbow trout is the most universal of the fish species reared in European aquaculture. It is raised from the North to South, East to West, in freshwater and seawater. It is harvested at different sizes, and is the basis of a range of different finished products. It is also the “oldest” of the fish species used for intensive farming in Europe, with a history in aquaculture dating as far back as the 1800s.

Despite the long experience with this species in aquaculture, malformations, and skeletal malformations in particular, are an important problem in modern rainbow trout aquaculture, irrespective of the rearing environment. In rainbow trout, malformations cause economical losses both in the hatchery sector and the on-growing sector. In addition, high numbers of malformed fish represent an ethical problem for the industry as a whole.

The causes of skeletal malformations in rainbow trout are probably as diverse as in other species, and one of the known causal factors is temperatures during egg incubation. In a previous study, the relation between temperature during embryonic development and malformations was established. The study showed that the best results were obtained when eggs were incubated at 10°C, and that relatively small effects on malformations were observed between 8°C and 12°C.

This study was, however, done with Norwegian eggs, and an important objection from producers from other geographic areas was that eggs from Norwegian stocks were not necessarily representative for other geographic strains of the species. In addition, it was noted that a significant proportion of the European production was done on triploid individuals, and specific information on the temperature tolerance of triploids compared to diploids was requested. Thus, as part of the FineFish project, an experiment was designed to address these issues.

The present study aimed to investigate the temperature tolerance of rainbow trout eggs of different geographic origins (north-south) and to investigate whether diploid or triploid rainbow trout have different temperature tolerance with regard to the development of skeletal malformations. In addition to these issues, it was decided to expand the range of test temperatures in the lower range, as there were indications from commercial production that there might be a lower limit for egg incubation temperatures in rainbow trout.

Experimental setup

Pooled egg groups originating from three different genetic strains (1, 2 and 3) were fertilised in their hatcheries of origin and transported to the experimental hatchery of Nofima Marine in Sunndalsøra, Norway for incubation.

Strain 1 consisted of eggs from Aqua Gen in Norway, the other two strains from southern altitudes. After fertilisation, half of the eggs from strain 3 were pressure treated (200 bar for 10 minutes at 10°C) to produce triploid fish.

The egg transport was done by courier, and was standardized as far as possible, so that all egg groups reached the destination within 24 hours post-fertilization.

The egg groups were split into small batches and incubated at 6, 10 or 14°C in triplicate small insulated units equipped with individual inlets and outlets (Figure 1).

The temperatures were kept stable from fertilisation to first feeding.

From first feeding, all fish were reared at 12°C, until termination of the experiment at approximately 30-40g.



Figure 1. Experimental units for hatching of rainbow trout eggs. The units have individual inlets and outlets and, each unit is insulated to insure stable temperatures.

Experimental Results

Survival after hatching

Embryonic temperature did not influence the survival rates from hatching to first feeding (range 67.6-78.1 %). However, one strain had an approximately 20% lower survival than the two others. Triploid groups had significantly lower survival than diploid groups from the same strain (38.4% and 61.3%, respectively).

Skeletal malformations

The most common skeletal malformations were fused or compressed vertebrae (see Figure 2).

The lowest prevalence of spinal malformations was obtained at 10°C, and fish originating from the 6°C eggs were comparable to those from 14°C eggs. There were also differences in number of fish with spinal malformations between the three geographic strains. Triploid groups had, not unexpectedly, a higher prevalence of fish with spinal malformations than diploid groups from the same strain. To a large extent, differences in prevalence were reflected also in the severity of lesions, so that the fish groups with the highest number of affected fish also had the most severe lesions.

Temperature effects on malformations in trout (*O. mykiss*)

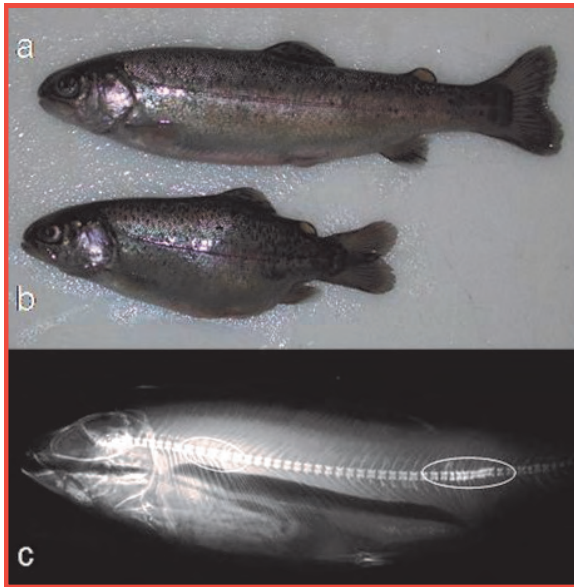


Figure 2. Rainbow trout with a normal vertebral column (a) and with a severe compression of the vertebrae in the caudal area (b). The radiograph (c) shows examples of compressed and fused vertebrae.

To give a better description of these observations, a “severity index” was calculated as:

% of affected fish x number of malformed vertebrae per affected fish (see Figure 3)

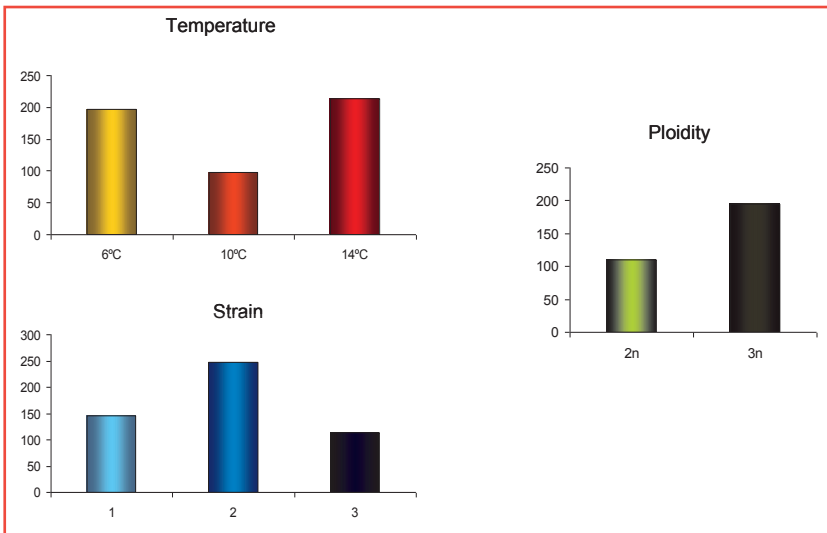


Figure 3. Effect of embryonic temperature, geographic strain and triploidy on severity of vertebral malformations, calculated as prevalence * number of affected vertebrae per fish with malformations.

Other malformations displayed a more variable pattern, but in sum, the results presented in Figure 3 are fairly representative of the overall results, in that

- eggs incubated at 10°C gave fish with the lowest rate of malformations and
- the results with incubation at 6°C and 14°C were inferior both in diploids and triploids.

Some strain specific malformations were observed in low numbers, and some malformations were more common in triploids, but these effects were of minor importance compared to the temperature effects.

Specific growth rate

The specific growth (SGR) rate from first feeding to approximately 40 g had a converse relation to increasing embryonic temperatures. Thus, the best growth rates in the juvenile stage were obtained in groups given the coldest water and longest development time during egg incubation.

It is important to note that from first feeding and onwards, all fish were reared at a common temperature (12°C), so that any differences in growth rate can be attributed to effects induced prior to first feeding.

When comparing strains, there were significant differences between them. Ploidity, on the other hand, did not affect the SGR (Figure 4).

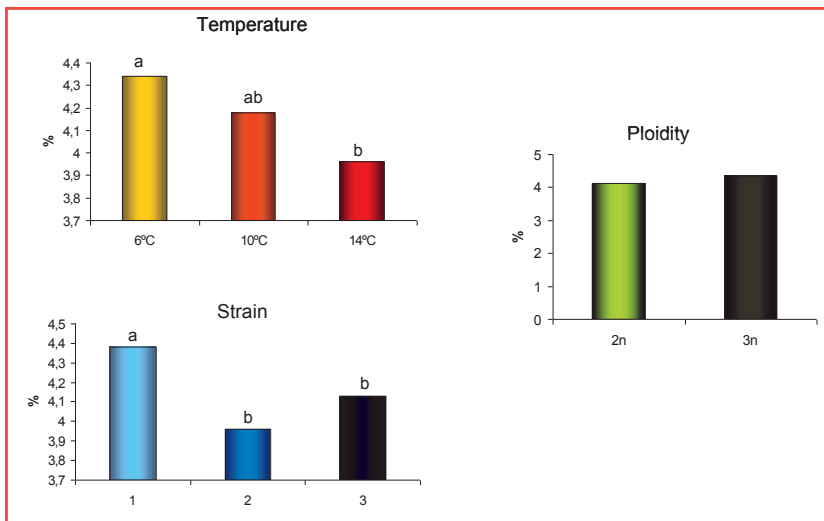


Figure 4. Effect of embryonic temperature, geographic origin and triploidy on the specific growth rate (SGR) from first feeding to approximately 40 g size. Different letters means statistically significant differences.

Conclusions and recommendations

The results confirm previous findings that the optimal temperature for incubation of rainbow trout eggs and yolk sac fry is 10°C, and this conclusion seems to be valid for each of the three European strains that were tested, despite the different geographic origins.

The study clearly showed that to achieve a normal development in rainbow trout an incubation temperature of 14°C is too high while 6°C is too low.

When combined with results from previous studies it can be concluded that rainbow trout should be incubated at temperatures between 8°C and 12°C, and that 10°C seems to be optimal for this species.

One of the strains generally showed inferior results compared to the other two strains. This may, however, be due to the fact that these eggs were stripped at the end of the local spawning season and also were obtained from females that had been stripped repeatedly. Thus, this is likely to be a result of low egg quality, rather than a specific strain effect. Other than that, there were some strain-specific effects on malformations, but the temperature response was the same for all three strains, and also for the triploid groups.

Triploid groups generally displayed higher malformation rates than diploid groups, which is in accordance with earlier studies. Thus, the obvious advantages of using triploids must be weighted against problems associated with the commercial production of all-female triploid females for each production area and market.

High embryonic temperature (14°C) resulted in a low SGR during first feeding, but the SGR did also differ between strains. This could be due to a different genetic background with regard to different genetic improvement intensity (breeding). There was no difference in SGR between diploid and triploid groups.

Recommendations:

The egg incubation temperature for rainbow trout, both diploid and triploid, should be controlled between 8 and 12°C to control malformations, irrespective of the individual genetic strain.