Morphological features and histological structure of the musculature of two trout phenotypic forms when reared in warm water of a power plant

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Abstract. The paper studies the effect of rearing in stocking ponds using the warm discharge water of the Smolensk NPP on the growth and trout meat quality. Some morphological indicators of trout cultivation are presented. The histological studies of the musculature of golden and typically colored trout are presented. It was revealed that the golden trout musculature grows with a predominance of hyperplasia of muscle fibers compared to the typically colored trout. It was shown that trout rearing using NPP cooling ponds does not lead to excessive accumulation internal fat and gives good results.

1 Introduction

In modern aquaculture, of great practical interest is the economic use of cooling ponds of various power plants for the rearing. The creation of cage farms on thermal waters does not require large capital investments and land acquisition [1]. Fish farming in warm waters is not only a source of food production, but also a tool of resource-saving technology.

However, when the growth rate is high, excessive deposition of internal fat may be observed. In this case, the buyer pays not for a valuable food product – meat, but for fat when selling whole fish. In a number of foreign countries, much attention is paid to this aspect. Also, other methods in fish farming intensification are becoming increasingly popular, such as feeding from automatic feeders according to need [2].

Among the aquacultures, salmonids achieve the greatest diversity. New breeds and forms of this family appear. Of considerable interest are the color forms, such as the golden trout. In this connection, our study purpose is to investigate the effect of warm-water power plant rearing on the growth and the muscle histological structure of trout.

The study of formation and growth of muscle at the histological structure level helps to improve the technology of rearing and implementation timeline, and also allows to reasonably assess the fish technological and nutritional quality.

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2 Materials and methods

The experiment was carried out in the stocking ponds of the cage farm located in the Smolensk NPP reservoir. Two stocking ponds contained rainbow trout of typical color (*Parasalmo mykiss Walbaum*) and two others contained golden trout. Golden trout has an amber-yellow coloration with a brownish-black maculation on the back.

The area of each stocking pond was 10 m², the depth was 3.0 m. The water temperature during the experiment varied from 11 to 15 °C. During the experiment, oxygen dissolved in water was at 90-100% saturation. Other hydrochemical indicators were also within the standard (industry standard 15.372.87). During the experiment, trout were given feed concentrate with a protein of 46-48 % and fat of 14-16%.

For the entire period, the fish mass varied 150 to 900 g. To control the growth, 10% of the total number of fish were randomly selected and weighed once every 15 days.

Histological samples were taken at the level of the dorsal fin. Samples were fixed in 10% formalin. After washing the samples from the fixative with running water, they were treated with gelatin solutions of increasing concentrations (7, 12.5, and 25%). Samples were stained with Sudan III (Vekton, Russia) and hematoxylin (Abris+, Russia) according to the Carazzi method. The measurement of muscle fiber diameters was carried out according to a generally accepted method.

3 Results

During the experiment, the average fish mass increased by 48.9% in the golden form and by 41.4% in typically colored trout. Regardless of the initial weight of the fish, by the end of the experiment, on average, the golden trout was larger than the typically colored trout. In ponds with smaller fish, this difference was about 25%. At the same time, the yield of ichthyomass was 24.3 and 22.7 kg/m³ for golden and typically colored trout, respectively.

The survival rate in all ponds was at a high level and was 96-98%. It was found that the FCR of both forms was between 1.7-1.71.

In the middle of the experiment, the relative mass of fish liver decreases slightly and increases by 18.5% in golden trout and by 32% in rainbow trout by the end of rearing. However, the value of the liver index did not exceed the limits of the physiological norm.

There was an increase in the growth rate and activation of the storage material accumulation in muscles, as well as the process of fat accumulation in the fish body cavity.

In December, the relative mass of visceral fat increased by more than 2 times in both forms of trout (Table 1). At the end of the experiment, this indicator in typically colored trout decreased by 9.1% and more significantly decreased by 29.2% in golden trout. This may be due to the preparation for the formation of gonads.

The proportion of epaxial muscles exceeds hypaxial ones in golden trout by 10.8-18.3%, and in typically colored trout - by 6.3-19.0%.

During the experiment, there was a tendency to decrease the relative mass of red muscles in both forms of trout. This is probably due to the lower mobility of larger fish in ponds. This indicator decreased by 47.6% in golden trout, and by 30.7% in the typically colored form.

Most of the somatic musculature of fish is represented by the deep lateral muscle, named white because of its light coloring. The paired superficial lateral muscle is located directly under the skin along the midline. Because of its darker color, it is called red. The horizontal septa divide the fish axial musculature into epaxial (dorsal) and hypaxial (abdominal) parts. Of greatest interest are the relative indices of muscle mass which characterize the market condition of fish.
Table 1. Changes in some morphological parameters of two forms of trout (% of body mass).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>November</th>
<th>December</th>
<th>March</th>
<th>November</th>
<th>December</th>
<th>March</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body mass</td>
<td>348.4±17.1</td>
<td>269.5±16.3*</td>
<td>496.5±56.4</td>
<td>413.0±68.5</td>
<td>712.88±62.7</td>
<td>650.85±27.1</td>
</tr>
<tr>
<td>Visceral fat</td>
<td>2.2±0.25</td>
<td>1.6±0.11</td>
<td>4.8±0.27</td>
<td>4.3±0.59</td>
<td>3.4±0.40</td>
<td>3.9±0.70</td>
</tr>
<tr>
<td>Gonads</td>
<td>0.12±0.01</td>
<td>0.14±0.02</td>
<td>0.14±0.02</td>
<td>0.15±0.01</td>
<td>0.30±0.12</td>
<td>0.13±0.02</td>
</tr>
<tr>
<td>Liver</td>
<td>1.37±0.06</td>
<td>1.43±0.03</td>
<td>1.30±0.07</td>
<td>1.33±0.04</td>
<td>1.54±0.06</td>
<td>1.72±0.10</td>
</tr>
<tr>
<td>Carcass</td>
<td>76.0±0.31</td>
<td>76.6±0.33</td>
<td>76.0±1.05</td>
<td>76.7±0.47</td>
<td>74.5±1.00</td>
<td>76.1±0.55</td>
</tr>
<tr>
<td>Muscles</td>
<td>61.30±0.27</td>
<td>64.4±0.45*</td>
<td>56.8±1.24</td>
<td>63.59±0.73*</td>
<td>62.0±1.73</td>
<td>62.3±1.19</td>
</tr>
<tr>
<td>Red muscle</td>
<td>1.50±0.14</td>
<td>1.55±0.11</td>
<td>1.48±0.15</td>
<td>1.38±0.13</td>
<td>0.89±0.13</td>
<td>1.22±0.22</td>
</tr>
<tr>
<td>White muscle</td>
<td>59.78±0.61</td>
<td>62.85±0.60*</td>
<td>55.31±1.38</td>
<td>62.21±0.73*</td>
<td>61.10±1.77</td>
<td>61.08±1.37</td>
</tr>
<tr>
<td>Epaxial musculature</td>
<td>32.28±0.18</td>
<td>34.62±0.55*</td>
<td>29.85±0.74</td>
<td>32.76±0.54*</td>
<td>33.35±1.10</td>
<td>33.11±0.87</td>
</tr>
<tr>
<td>Hypaxial musculature</td>
<td>29.00±0.33</td>
<td>29.83±0.57</td>
<td>26.94±0.88</td>
<td>30.83±0.64*</td>
<td>28.64±0.86</td>
<td>29.15±0.71</td>
</tr>
</tbody>
</table>

* - The difference compared to golden trout is significant at P<0.05

At the beginning and middle of the experiment, the golden form lagged behind the typically colored one in this parameter, first by 5 % and then by 12 % (the differences are significant). However, by the end of the experiment, the values of relative muscle mass were equal in both forms.

According to our data in the hypaxial part, the typical colored trout has 27.9 % less fat content than the golden trout, and in the epaxial part, the fat content is 22.1 % higher.

There is significantly less muscle tissue in the red musculature than in the white one, but there are much more fat layers [3]. Numerous studies have shown that the white fibers diameter is larger than the diameter of red ones [4-6].

Fish muscle growth with early development of myotomes involves two processes: thickening of existing muscle fibers (hypertrophy) and formation of new ones (hyperplasia) [4;7]. This is true for both types of fibers: white and red. The correlation between these processes, their role in increasing the muscle mass depends on fish species, age, growth intensity, as well of morphofunctional muscle type and other factors [6]. And hyperplasia, according to some estimates, can provide 70-90% muscle tissue growth [5].

During the experiment, the dimensional structure of the white muscle fibers of both forms remained practically unchanged. Fibers from 10 to 160 µm were observed. More than 30 percent of the fibers were in the 40-60 µm size range, and over 75% of all golden trout fibers were in the class range of 20-80 microns.

In typically colored trout in contrast to the golden form, when reaching a body length of 25-30 cm, about 65% of all fibers were between 20-80 µm, which can be explained by the predominant role of hypertrophy in the white muscle growth (Figure 1).

During the experiment period, red musculature in body weight decreased from 1.3% to 0.9% in golden trout and from 1.6% to 1.2% in trout with typical coloration (the absolute increase in red musculature is also less in the golden form).

In November and December, trout with typical coloration have 2.5 and 1.5% more fine fibers up to 20 µm than golden trout (Figure 2).
**Fig. 1.** Dimensional structure of white fibers of two trout forms.

**Fig. 2.** Dimensional structure of red fibers of two trout forms.
This may indicate a lower level of hyperplasia in the golden form. In both forms of trout, at the end of the research (March), the size range of red muscle fibers dramatically expanded. If before the middle of the experiment (December) the fiber diameters reached a maximum of 45-50 µm with a peak in the interval of 25-30 µm, then by the end of the study (March) the fiber diameters increased to 70 µm. At the same time, the largest number were fibers with a diameter of 30-35 µm in trout with typical coloration and 30-45 µm in golden trout. Thus, we see that the red muscle growth when reaching a fish body length of 30-35 cm occurs mainly due to hypertrophy.

4 Discussion

The use of rearing in stocking ponds using the warm discharge water of the NPP for the purposes of fisheries is an important reserve for improving the efficiency of commercial fish farming.

Our research has shown that the content of internal fat in both forms does not exceed the level typical for trout reared in artificial conditions [9]. In December, golden trout is inferior in relative muscle content to the typically colored form. However, by the end of the experiment, this indicator is equalized.

The relationship between the muscle fiber diameter and the meat taste is known [8]. The smaller the diameter of the muscle fiber, the more tender the meat. The studied features of the muscle histological structure of the two rainbow trout forms indicate a number of properties associated with the meat tenderness and density. Judging by them, it can be assumed that golden trout meat is more tender than trout with typical coloration, since the musculature mainly consists of white muscles. The obtained increase in body weight does not exhaust the possibilities of trout growth in the cooling ponds of the Smolensk NPP.

5 Conclusion

Considering our data, it can be concluded that it is more profitable to grow golden trout over 400 g in warm waters of power plants, when the relative mass of muscle is not inferior to that of typically colored trout. In other morphological features, the golden trout was not inferior to the typically colored form.

Trout rearing using waste water from the power plant makes it possible to extend the growing season and create an optimal temperature regime ensuring high growth of fish weight without deteriorating the muscle tissue quality and excessive accumulation of internal fat.

References


