

Effects of water temperature and different types of feed on specific growth rate (SGR) and thermal unit growth coefficient (TGC) of rainbow trout (*Oncorhynchus mykiss*) reared in cages

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Abstract

The aim of this study was to analyze the effects of water temperature and different types of commercial feed on the specific growth rate (SGR) and thermal unit growth coefficient (TGC) of rainbow trout reared in cages. The experiment was carried out in six cages during six months in two separate periods (October-January and April-July). Rainbow trout (n = 25,000 per period), from a common pool were placed into the 6 cages. Six types of commercial feed were used. The average initial weight of rainbow trout in October was 95.3 g, and in April it was 96.1 g. Fish weight gain controls were performed every 15 days, on a sample of 100 fish/cage. Specific growth rate (SGR) and thermal unit growth coefficient (TGC) were used for the analysis and prediction of rainbow trout weight growth. The average water temperature in October - January was 7.76 °C (4.1 - 12.5 °C), and in April - July 12.95 °C (7.5 - 26.9 °C). In both periods, SGR and TGC were higher in fish fed commercial diets with higher protein and fat content with lower feed consumption. In the period of low water temperatures, the predicted fish weight calculated from SGR and TGC are similar, but they do not agree with the observed weight growth. The increase in water temperature results in higher SGR and TGC, but due to high and significant variations in water temperature and increase in fish weight, the growth rate is moderate. With increasing water temperature, the observed increase in weight compared to the predicted weight of rainbow trout is similar. The SGR model is not applicable when there is no data on the achieved weight growth, and a more realistic prediction of the weight growth of rainbow trout is using the TGC model.

Key words: temperature, SGR, TGC, rainbow trout

INTRODUCTION

Assessment of the energy value and effects of different types of commercial feed on rainbow trout (*Oncorhynchus mykiss*) weight growth and environmental conditions in one production cycle can be the basis for predicting weight growth in the next production cycle. Many factors (water temperature, body size, stocking density, feed quality, etc.) affect on feed consumption and growth rate (Jobling, 1993). Considering that fish are poikilothermic organisms, the temperature of the breeding environment determines the effects on their metabolism and growth potential (Brett, 1979). The effects of temperature on metabolism, feed consumption and growth rate have been the subject of numerous studies (Jensen, 1985, McKay & Gjerde, 1985, Austreng et al., 1987, Sevik et al., 1998, Okumus, 1999 et al.).

Frequently used growth models of salmonid fish species in aquaculture are specific growth rate (SGR) and thermal unit growth coefficient (TGC). The disadvantage of the SGR model is that it does not take water temperature into account, so the application of this model is limited to shorter periods of time in stable growing environment conditions. The higher the body mass of juvenile fish, the lower the growth rate (Márquez et al., 2024).

Iwama & Tautz (1981) developed the TGC model, which was modified by Cho (1992) and is used for weight growth analysis, growth prediction and planning during fish farming. This model also takes into account water temperature, which has a direct effect on fish growth. The model is easy to use, where it is necessary to know the initial data on fish growth, after which it can be used to predict weight growth based on the established growth potential. The popularization of the model implies the ease of use and adaptability of fish weight growth data to predict the growth of fish of different sizes (Cho & Bureau, 2000). Uncritical use of the TGC model leads to a serious presence of design errors (Jobling, 2003). From the production cycle, the final TGC is determined by extrapolation, which can be used to predict growth in the next production cycle, assuming that there are no extreme variations in some factors and fish stocks (Cho & Bureau, 1998). The use of any model for evaluating the growth of the weight of farmed rainbow trout implies conducting research on the growth of the weight of rainbow trout in specific breeding conditions (water temperature, feed, etc.) and for a specific population of rainbow trout. Understanding the endogenous (age, etc.) and exogenous (photoperiod, etc.) influences on growth rate per degree day and weight exponent will likely improve the fit of the TGC growth model (Dumas et al., 2007).

The aim of this study was to analyze the effects of water temperature and different types of commercial feed on the specific growth rate (SGR) and thermal unit growth coefficient (TGC) of rainbow trout reared in cages.

MATERIAL AND METHODS

The experiment was carried out in a cage system for rainbow trout breeding during two periods (October - January and April - July). The effective production volume of the cage was 162.5 m³/cage (5 m x 5 m x 7 m). The experiment lasted six months in two separate periods (3 months/period), in 6 cages were 25,000 individuals/period (50,000 individuals in total, in both periods). Six types of commercial feed with different proportions of crude protein (CP), crude fat (CL), and nitrogen-free extract (NFE) were used, and the label of the feed also represents the label of the cage in which the rainbow trout is placed (SP/SM/NFE: 1 = 44/14/21; 2 = 48/26/17; 3 = 42/22/15; 4 = 42/23/17.2; 5 = 44/26/13; and 6 = 42/18/21.5).

Water temperature was measured daily at 3 depths next to the cage with a thermo-oximeter with a probe on an extension cable (Oxy Guard - Denmark). At the beginning of each period, the average weight of fish (g/fish) in each cage was determined with a digital scale (Acculab) on a random sample of 100 fish/cage (total of 600 fish from 6 cages). The average initial weight of rainbow trout in October was 95.3 g/fish (min. 93.97 g/fish, max. 97.95 g/fish), and in April 96.1 g/fish (min. 94.08 g/fish, max. 99.43 g/fish). Weight gain controls of rainbow trout were performed every 15 days, on a random sample of 100 fish/cage (600 fish from 6 cages in total). Before manipulation, the fish was anesthetized in a solution of chlorobutanol and 96% alcohol (4 g of chlorobutanol was dissolved in 11 ml of 96% alcohol and mixed with 35 liters of water).

Fish weight growth was analyzed using specific growth rate (SGR) and thermal unit growth coefficient (TGC). SGR is calculated according to the formula:

$$SGR = ((\ln FBW - \ln IBW)/D)*100$$

SGR – specific growth rate; FBW – final body weight (g/fish); IBW – initial body weight (g/fish); ln – natural logarithm; D – number of days

Prediction of fish body weight based on total SGR was calculated according to the formula:

$$W_2 = W_1 \times e^{SGR \times (t_2 - t_1) / 100}$$

W₂ - weight prediction (g/fish); W₁ - initial weight (g/fish); e – base of natural logarithm; t₂-t₁ - number of days

Thermal unit growth coefficient (TGC) is calculated according to the formula:

$$TGC = [FBW^{1/3} - IBW^{1/3}] / \Sigma [T \times D] \times 100$$

Prediction of fish body weight based on total TGC was calculated according to the formula:

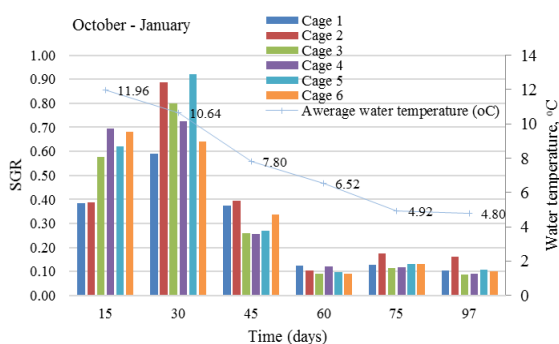
$$PBW = [IBW^{1/3} + (TGC/100 \times T \times D)]^3$$

TGC – thermal unit growth coefficient; FBW – final body mass (g/fish); PBW – prediction body weight (g/fish); IBW - initial body weight (g/fish); T - water temperature (°C); D - number of days

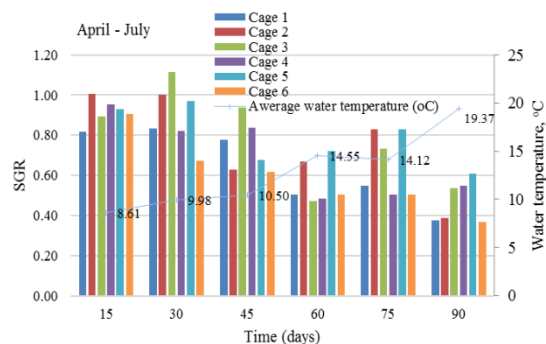
RESULTS AND DISCUSSIONS

Seasonal variations in water temperature during the research period directly affected the intake and utilization of feed, as well as the growth of rainbow trout weight. From October to January, there was a constant fall in water temperature, which averaged 7.76 °C (min. 4.1 °C; max. 12.5 °C), during this period there was no horizontal and vertical thermal stratification of the water. In the period April-July, the water temperature is constantly increasing and was on average 12.95 °C (min. 7.5 °C; max. 26.9 °C) with expressed vertical and absence of horizontal thermal stratification of the water.

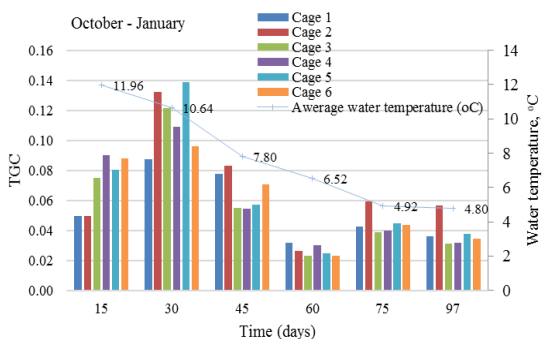
The graphical presentation of SGR (Graphs 1 and 2) and TGC (Graphs 3 and 4), calculated in fifteen-day intervals based on the determined weights at the controls, indicates a decrease in SGR and TGC, which can be explained by a fall in water temperature (October - January) and an increased weight of fish in the period of growth and expressed variations in water temperature (April - July).



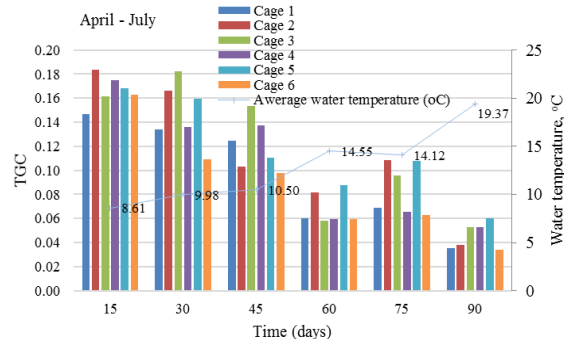
Graph 1. Average water temperature and SGR of rainbow trout by cages and days (October - January)



Graph 2. Average water temperature and SGR of rainbow trout by cages and days (April - July)



Graph 3. Average water temperature and TGC of rainbow trout by cages and days (October - January)



Graph 4. Average water temperature and TGC of rainbow trout by cages and days (April - July)

Differences in SGR and TGC within the same periods and controls (days) in different cages are the result of using feed with different contents of CP, CL and NFE. During the period October - January, the highest SGR and TGC were achieved in fish from cages 2 and 5 (fed with feed with the highest proportion of protein and fat). The variability of SGR and TGC is also present in the period April-July, with more favorable environmental conditions (water temperature, etc.) for good growth of fish weight. The increase in water temperature affects the growth of nutrition level and the growth of fish weight. Although the physical and chemical characteristics of the water (with significant variation) were more favorable for raising rainbow trout in the period April-July, from 30 days there was a drop in SGR, and from 75 to 90 days of the experiment, the lowest SGR and TGC were recorded (graphs 2 and 4). The tendency of a decline in the values of SGR and TGC during the period from April to July, regardless of the positive trends in observed fish weight growth, is a consequence of high water temperatures, significant fluctuations in water temperature, and increasing fish weight, which is consistent with the statements of Cain & Garling (1993) and Sevik et al. (1998) that an increase in body weight leads to a

decrease in growth rate. The increase in water temperature (7.5 - 26.9°C) in the period April - July caused a decrease in TGC, which confirms the statements of Bailey & Alanära (2001) and Aunsmo et al. (2014) that TGC tends to decrease with increasing water temperature.

Feeding with commercial feed of different energy values in the same conditions of the breeding environment (within each period) resulted in different growth of rainbow trout weight and differences in SGR and TGC within the same and different periods of the experiment (October - January and April - July), in proportion to the energy content in feed (Table 1).

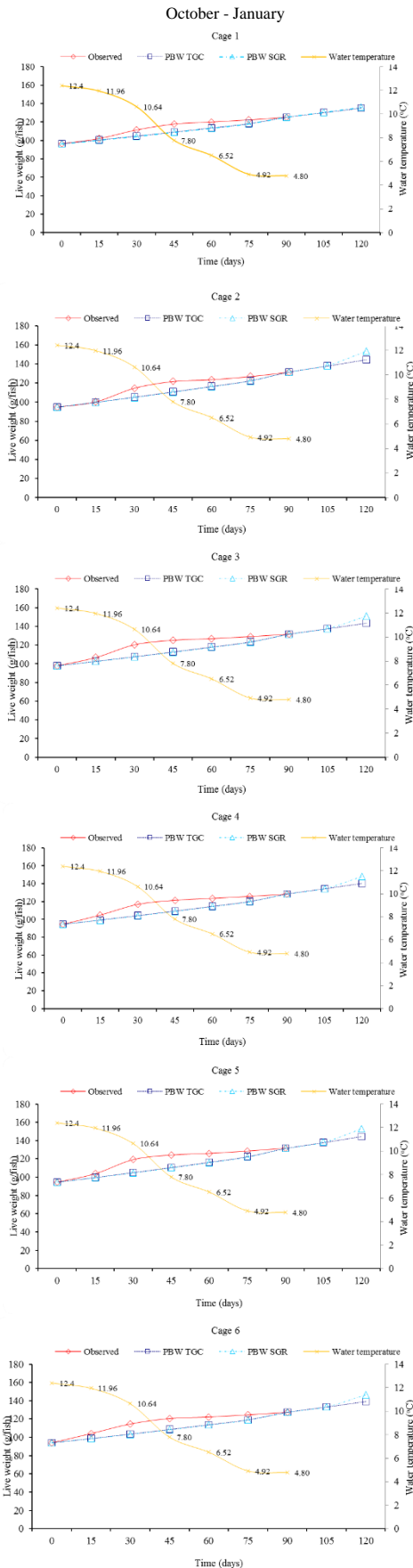
Table 1. Observed weight (g/fish) of rainbow trout at the beginning and end of the experiment with total SGR and TGC (October-January and April-July)

The period of realization of the experiment	October – January				April - July			
Duration (days)	97				90			
Average water temperature (min.-max.)	7,76 °C (4,1 – 12,5 °C)				12,95 °C (7,5 - 26,9 °C)			
Cage	IBW (g/fish)	FBW (g/fish)	SGR	TGC	IBW (g/fish)	FBW (g/fish)	SGR	TGC
1	96.28	125.23	0.271	0.0557	94.08	167.67	0.642	0.084
2	94.75	131.50	0.338	0.0698	97.32	191.84	0.754	0.101
3	97.95	131.62	0.305	0.0633	95.04	192.01	0.781	0.104
4	94.29	128.26	0.317	0.0652	99.43	185.26	0.691	0.092
5	94.56	131.47	0.340	0.0702	96.33	195.95	0.789	0.106
6	93.97	127.35	0.313	0.0643	94.39	161.23	0.595	0.077

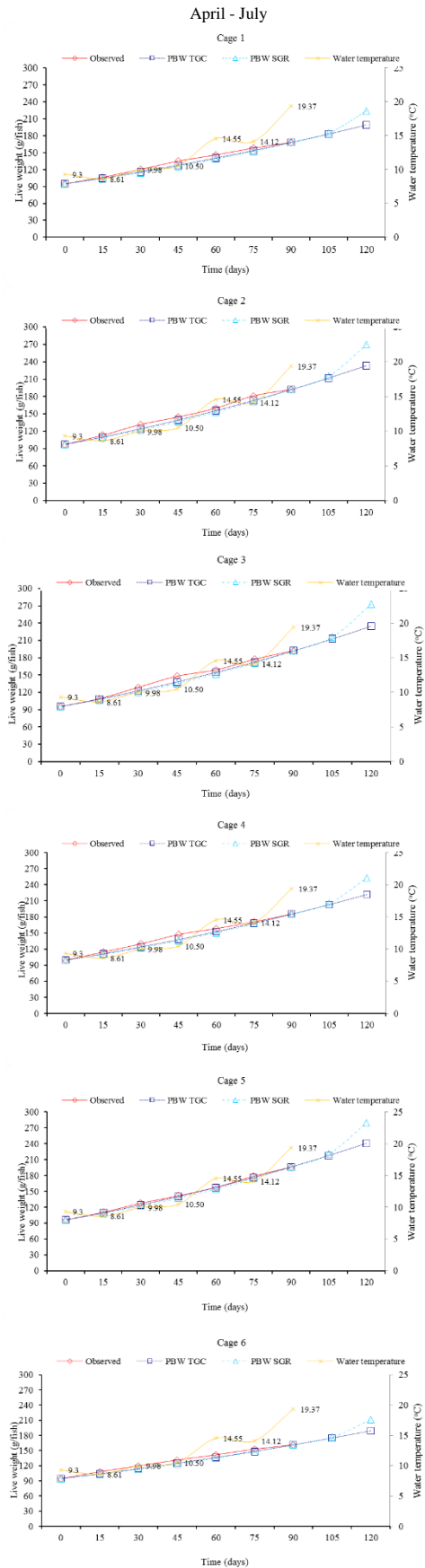
IBW – initial body weight (g/fish); FBW – final body weight (g/fish); SGR - specific growth rate;
TGC - thermal-unit growth coefficient

Graphs 5 and 6 show the observed (97/90 days) and predicted weight growth (up to "120 days") of rainbow trout using the SGR and TGC models, which indicate a similar trend in predicting fish weight growth based on SGR and TGC, and more pronounced deviation from the observed increase in weight during the period of falling water temperature (October - January) and a smaller deviation due to the increase in water temperature (April - July).

The observed weight growth of rainbow trout during the period October - January in most cases, except for the initial and final body weight, differs from the predicted weight growth of fish per cage and day, which indicates that at low water temperatures these models are not acceptable for determining the weight growth of fish. An increase in water temperature and feeding with feed with a higher protein and fat content (cages 2 and 5) leads to a more optimal utilization of the growth potential of rainbow trout and smaller differences in the determined TGC. The effects of feed with a lower protein and fat content (cages 1 and 6) when the water temperature increases are a more uniform and slower growth of fish weight, and a higher total feed consumption. The weight growth potential of rainbow trout is not optimal when the water temperature varies greatly, and Peña-Ortega & Bureau (2006) state that at a constant water temperature, the conditions for manifesting the growth potential are more optimal. The determined values of TGC of rainbow trout in this research, with significant variations in water temperature (min. 7.5 °C; max. 26.9 °C), are significantly lower compared to the results of Savić and Mikavica (2010), who state that they are at a lower and more stable temperature water (average from 8.05 to 8.47 °C) and the use of different types of commercial feed in the classic rainbow trout breeding system, TGC values were from 0.119 to 0.169.



Graph 5. Average water temperature, observed and predicted (SGR and TGC) weight growth (g/fish) of rainbow trout (October – January)
IBW - initial body weight; FBW - final body weight; PBW - predicted body weight



Graph 6. Average water temperature, observed and predicted (SGR and TGC) mass growth (g/fish) of rainbow trout (April - July)
IBW - initial body weight; FBW - final body weight; PBW - predicted body weight

The observed and predicted growth of rainbow trout weight in the period April - July are very similar. In the case of fish from cage 5, the observed and predicted fish weight per cage and day were found to be almost identical. However, when there is no data on the observed fish weight growth, there is a significant deviation of the predicted fish weight growth determined using these two models. Which indicates that, although a commonly used method for analyzing fish weight growth based on known production characteristics, SGR is not suitable for predicting fish weight growth. SGR is based on the difference of the natural logarithm of the final and initial body weight in relation to the number of days, while TGC has a more complex approach because it also takes into account the water temperature. SGR can be used to analyze observed weight growth but is not suitable for predicting fish weight as confirmed by Bureau et al. (2000) who state that the SGR model is inappropriate for predicting fish growth. SGR has a linear growth trend, probably due to the natural logarithm that is not appropriate for the growth curve of many species of fish grown in optimal conditions (Bureau et al., 2000) and which does not take into account water temperatures, while TGC gives a more realistic increase in fish weight.

CONCLUSION

Low water temperatures result in lower SGR and TGC, which are slightly higher in fish fed with commercial feed with higher protein and fat content (cages 2 and 5) with lower feed consumption and lower in fish fed with feed with lower protein and fat content. With the increase in water temperature, the highest SGR and TGC were achieved in fish from cage 5 with less feed consumption, and the lowest in fish from cage 6. According to the determined values of SGR and TGC, the effects of feed with lower energy values (cages 1 and 6) are more uniform and lower weight growth rainbow trout with higher feed consumption. The increase in water temperature results in higher SGR and TGC, but due to high and significant variations in water temperature and increase in fish weight, the growth rate is moderate. With increasing water temperature, the observed increase in weight compared to the predicted weight of rainbow trout converted from SGR and TGC is similar. The SGR model is not applicable when there is no data on the achieved weight growth, and a more realistic prediction of the weight growth of rainbow trout is obtained using the TGC model.

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