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***Short communications***

# OXYGEN CONSUMPTION AND AMMONIA EXCRETION BY EURASIAN PERCH (*PERCA FLUVIATILIS* L.) REARED UNDER OPTIMAL THERMAL CONDITIONS

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ABSTRACT. The aim of the study was to determine the oxygen consumption (OC, mg $O_2$ $kg^{-1}$ $h^{-1}$) and ammonia production (AE, mg TAN $kg^{-1}$ $h^{-1}$) of perch reared in a recirculating system at the optimal temperature for this species of 23°C. The studies were conducted when the fish were undergoing intense fattening on artificial feed. Measurements of metabolic rate were taken 24 hours per day in six size groups of fish (mean body weights (BW) in each group – 18.4, 30.7, 46.4, 56.5, 67.8, 82.3 g). Within the studied perch size range, OC decreased from 336.2 to 185.0 mg $O_2$ $kg^{-1}$ $h^{-1}$, and AE from 22.0 to 5.6 mg TAN $kg^{-1}$ $h^{-1}$. An increase in body weight by 1 g led to an average decrease in oxygen consumption by a mean of 2.53 mg $O_2$ $kg^{-1}$ $h^{-1}$ and ammonia excretion by 0.28 mg TAN $kg^{-1}$ $h^{-1}$. During the analyzed period, the body weight of perch, the arithmetic dependence between OC-BW and AE-BW, was linear and the determination coefficients $R^2$ of the linear regression equations describing these relationships were highly statistically significant at a value exceeding 0.9.

Key words: PERCH (*PERCA FLUVIATILIS*), OXYGEN CONSUMPTION, AMMONIA EXCRETION, RECIRCULATING SYSTEMS

The cultivation of percoid fish (stocking material and commercial-sized fish) in recirculating systems is becoming increasingly common. Significant progress has been made in the development of methods for rearing and fattening Eurasian perch, *Perca fluviatilis* L. (Fontaine et al. 1996, Kestemont and Mélard 2000), yellow perch, *Perca flavescens* (Mitch.) (Malison and Held 1992), walleye, *Sander vitreus* (Mitch.) (Malison and Held 1996, Summerfelt R.C. 1996, Summerfelt and Summerfelt 1996), and pikeperch, *Sander lucioperca* (L.) (Zakęś 1999, Zakęś et al. 2000a). Studies of the possibilities of fattening Eurasian perch using various cultivation systems were initiated in the 1990s (*e.g.*,

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Fontaine et al. 1996, Mélard et al. 1996). It should be emphasized that, to date, research has focused primarily on determining the nutritional requirements of this species (Fiogbe et al. 1996, Juell and Lekang 2001, Kestemont et al. 2001, Xu et al. 2001). Studies have also investigated the impact of other biotic and abiotic factors on basic rearing parameters that include primarily the growth and survival of larval and juvenile perch. It has been established that perch in the body weight range from 3 to 300 g attain the maximum growth rate at a temperature of 23°C. The growth rates of fish held at both higher (27°C) and lower water temperatures (11-20°C) were significantly lower (Mélard et al. 1996).

In addition to determining nutritional and environmental requirements, it is essential to know the oxygen consumption and ammonia excretion rates of a given species if cultivation biotechniques are to be perfected. Concentrations of oxygen and ammonia are the basic parameters that limit fish cultivation (Westers and Pratt 1977, Wedemeyer 1996, Singh et al. 1999). This type of information is especially important when fish cultivation takes place in recirculating systems (Summerfelt S.T. 1996). It is of particular utilitarian importance to determine the metabolic rate of a given species under conditions in which it attains the optimal growth rate.

The aim of the current study was to determine the levels of oxygen consumption and ammonia excretion of juvenile perch (body weight 18.4-82.3 g) reared in a recirculating system on artificial feed and at a water temperature of 23°C, which provide conditions for the optimal growth rate of this species.

The material for the study was obtained from the Dgał Experimental Hatchery in Pieczarki, Inland Fisheries Institute in Olsztyn (northeastern Poland). After the initial rearing phase on artificial feed (Szczepkowski, unpublished data), which lasted until the fish had attained an average body weight of approximately 12.5 g, the fish were transported in plastic bags with oxygen to the Aquaculture Department of the Inland Fisheries Institute in Olsztyn. The fish were stocked into three 200 $dm^3$ rearing tanks that were part of a recirculating system. One hundred fish were placed in each tank, and the initial stocking density was about 6.3 kg $m^{-3}$. During the four-month rearing experiment, the water temperature was maintained at a constant level that was optimal for the intense growth of this species – 23.0 (± 0.2)°C (Mélard et al. 1996). Water flow was maintained at 4 $dm^3$ $min^{-1}$ (1.2 exchanges per hour). The oxygen concentration (DO) of the water flowing into and out of the tanks did not drop below 7.45 or 4.80 mg $O_2$ $dm^{-3}$, respectively. Concentrations of total ammonia nitrogen (TAN = $NH_4^+$-N + $NH_3$-N) at the inflow and outflow did not exceed 0.03 and 0.22 mg TAN $dm^{-3}$, respectively (Table 1). A 24-hour light cycle was applied (24L:0D) at a light intensity in the rearing room of 100-150 lx.

**TABLE 1**

Characteristics of fish, feeding, and water during the experiment (mean (SD); N = 3)

| Parameter | Fish size group | | | | | |
|---|---|---|---|---|---|---|
| | Group I | Group II | Group III | Group IV | Group V | Group VI |
| Fish | | | | | | |
| Body weight (g) | 18.4 (0.3) | 30.7 (1.7) | 46.4 (2.1) | 56.5 (0.6) | 67.8 (4.2) | 82.3 (4.8) |
| Stocking density (kg $m^{-3}$) | 9.3 | 11.8 | 12.0 | 13.2 | 14.0 | 16.9 |
| Feeding | | | | | | |
| Feed ration (% BW $d^{-1}$) | 2.0 | 2.0 | 1.5 | 1.2 | 0.9 | 0.9 |
| Granule diameter (mm) | 1.5 | 1.5 | 1.5 | 2.0 | 2.0 | 2.0 |
| Water inflow | | | | | | |
| DO (mg $O_2$ $dm^{-3}$) | 7.73 (0.02) | 7.68 (0.08) | 7.68 (0.07) | 7.71 (0.05) | 7.53 (0.12) | 7.45 (0.14) |
| TAN (mg TAN $dm^{-3}$) | 0.030 (0.001) | 0.023 (0.007) | 0.010 (0.003) | 0.010 (0.002) | 0.015 (0.004) | 0.008 (0.000) |
| Water outflow | | | | | | |
| DO (mg $O_2$ $dm^{-3}$) | 5.04 (0.02) | 4.80 (0.04) | 5.30 (0.09) | 5.31 (0.06) | 5.23 (0.05) | 5.01 (0.01) |
| TAN (mg TAN $dm^{-3}$) | 0.211 (0.014) | 0.220 (0.007) | 0.132 (0.007) | 0.112 (0.007) | 0.110 (0.007) | 0.084 (0.001) |

Commercial trout feed manufactured by Aller Mølle (Denmark) was used during the rearing period. The fish were fed for 18 hours per day (09:00 – 03:00) with an automatic feeder. In the first phase of rearing (fish BW 13-46 g), feed with a granulation of 1.5 mm was used (protein 53%, fat 14%, carbohydrates 10%; gross energy – 20.7 MJ $kg^{-1}$). When the fish attained a body weight range of 56-82 g, feed with a larger granulation size was used – 2 mm (protein 45%, fat 20%, carbohydrate 16%; gross energy – 21.6 MJ $kg^{-1}$) (Table 1).

Throughout the four-month rearing period, measurements of perch metabolic rate were taken six times (six fish size groups). The mean body weight of perch in the various groups ranged from 18.4 g (Group I) to 82.3 g (Group VI; Table 1). The procedure for measuring perch oxygen consumption and ammonia excretion in which calculations (formulae) and statistical analysis were performed was analogous to experiments conducted previously (Zakęś and Demska-Zakęś 2002, Zakęś et al. 2003). The rates of oxygen consumption (OC, in mg $O_2$ $kg^{-1}$ $h^{-1}$) and ammonia excretion (AE, in mg TAN $kg^{-1}$ $h^{-1}$) were calculated in consideration of the differences in oxygen (mg $O_2$ $dm^{-3}$) or ammonia (mg TAN $dm^{-3}$) concentration between the inflowing and outflowing water of the tank with the fish, the water flow rate ($dm^3$ $min^{-1}$) and fish biomass (kg). Water was sampled from all three rearing tanks (N = 3) in a daily cycle every 60 minutes.

The studies were continued until the perch had attained the minimum commercial size of 80-100 g (Tamazouzt et al. 1993). The current study confirmed the earlier findings of Mélard et al. (1996) that under stable, optimal thermal conditions perch can attain these sizes in the course of one rearing season.

In the analyzed fish size range (18-82 g), the mean oxygen requirement of perch decreased by 45%. In turn, the production of ammonia decreased even more significantly by 75% (from 22.0 to 5.6 mg TAN $kg^{-1}$ $h^{-1}$; Table 2).

**TABLE 2**

Rates of oxygen consumption (mg $O_2$ $kg^{-1}$ $h^{-1}$) and ammonia excretion (mg TAN $kg^{-1}$ $h^{-1}$) (mean (SD), N = 3) in six size-groups of juvenile Eurasian perch at 23°C

| Fish size group | Metabolic rate | | | Maximum/Mean |
|---|---|---|---|---|
| | Mean* | Minimum | Maximum | |
| | | Oxygen consumption | | |
| Group I | 336.2A (5.0) | 287.4 (19.4) | 370.2 (11.0) | 1.10 |
| Group II | 300.4B (13.1) | 231.9 (7.8) | 344.5 (5.6) | 1.15 |
| Group III | 261.9C (13.9) | 198.6 (4.5) | 303.7 (15.6) | 1.16 |
| Group IV | 215.6DE (8.6) | 158.8 (0.8) | 256.0 (13.7) | 1.19 |
| Group V | 192.0EF (0.7) | 170.0 (3.8) | 213.7 (6.3) | 1.11 |
| Group VI | 185.0F (0.7) | 159.1 (4.5) | 206.2 (1.2) | 1.11 |
| | | Ammonia excretion | | |
| Group I | 22.0A (1.7) | 14.0 (3.8) | 28.7 (2.0) | 1.30 |
| Group II | 19.9B (0.7) | 11.9 (0.1) | 27.7 (3.0) | 1.39 |
| Group III | 12.8C (1.0) | 3.2 (0.8) | 18.1 (1.4) | 1.41 |
| Group IV | 8.3DE (0.4) | 1.7 (0.4) | 12.8 (1.1) | 1.54 |
| Group V | 7.3EF (0.3) | 3.7 (0.3) | 10.0 (0.5) | 1.38 |
| Group VI | 5.6F (0.4) | 2.1 (0.6) | 8.4 (0.5) | 1.50 |

*Values in columns with the same letter index are not significantly different at P = 0.05*

When perch body weight increased by 1 g, the consumption of oxygen fell by 2.5 mg $O_2$ $kg^{-1}$ $h^{-1}$, and ammonia excretion fell by 0.28 mg TAN $kg^{-1}$ $h^{-1}$ (Fig. 1). Generally, in a wide range of fish sizes the dependence of metabolic rate on body weight is curvilinear. Not until the data logarithms have been determined does this dependence become linear (Schmidt-Nielsen 1994). For the perch body weight range in the current study, the arithmetic dependence among OC and BW as well as AE and BW were linear, and the determination coefficients $R^2$ were highly statistically significant at values exceeding 0.9 (Fig. 1). It should be emphasized that the dependencies determined here refer exclusively to fish with body weights exceeding 18 g. This is indicated by the

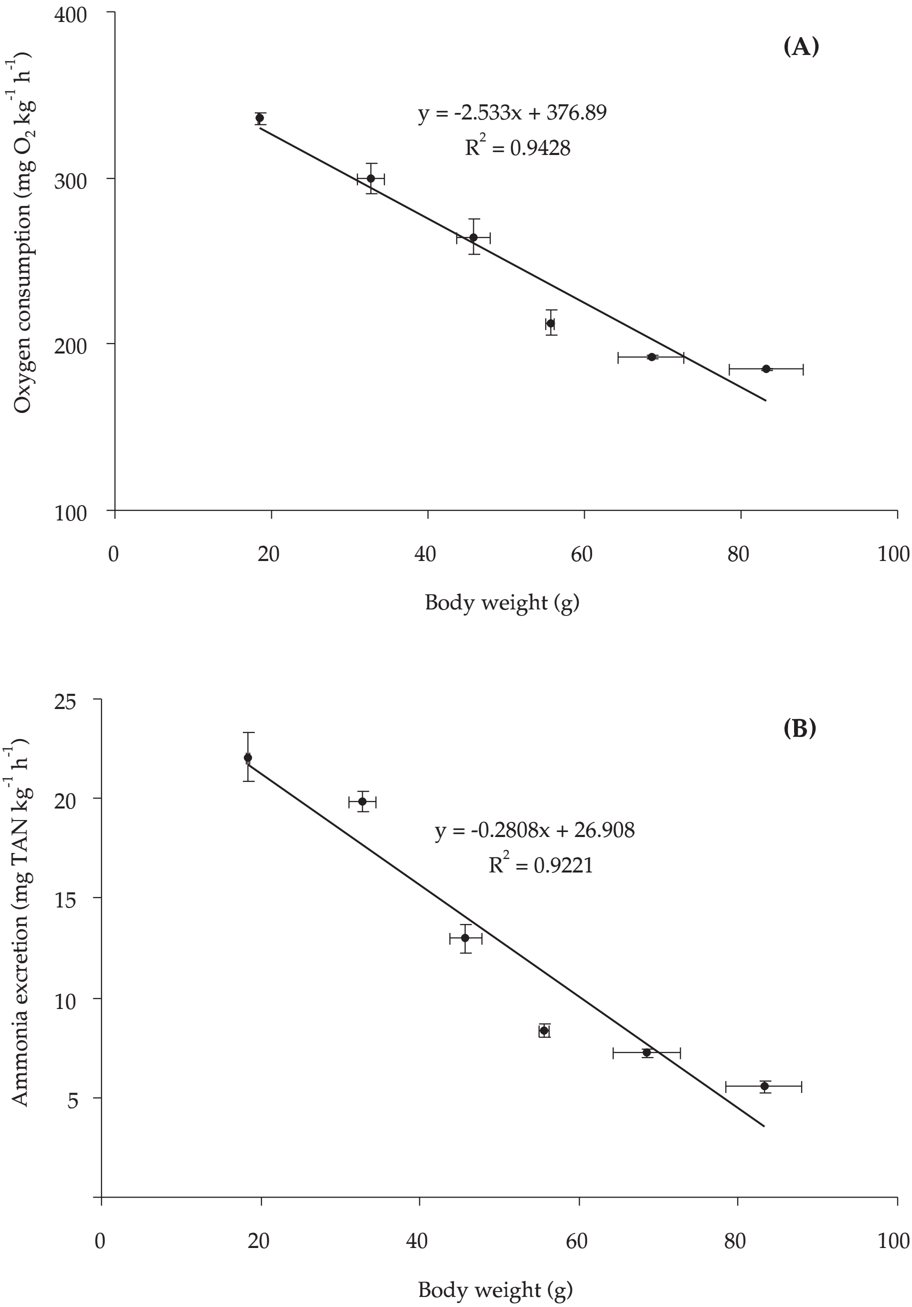


Fig. 1. Relationships of oxygen consumption (A) and ammonia excretion (B) to body weight (BW 18.4-82.3 g) of Eurasian perch reared at 23°C on artificial feed (mean ± SD).

comparison with empirical results of data calculated with mathematical formulae (Fig. 1). Previous studies were conducted by the authors on perch with body weights of 0.62 g and reared in recirculating systems in three water temperature variations (Zakęś et al. 2000b). It was confirmed by the authors that at a temperature of 23°C, the same temperature used in the current studies, the respective OC and AE values were 1088.08 $O_2$ $kg^{-1}$ $h^{-1}$ and 66.55 mg TAN $kg^{-1}$ $h^{-1}$. However, using the mathematical equations presented in the current study to calculate the oxygen consumption and ammonia excretion for perch of a body weight of 0.62 g produce OC and AE levels of just 375.3 mg $O_2$ $kg^{-1}$ $h^{-1}$ and 26.7 mg TAN $kg^{-1}$ $h^{-1}$, respectively.

In comparison with data obtained from studies of pikeperch conducted with very similar experimental procedures (fish size, water temperature, feeding), the metabolic rate of perch is faster (Zakęś 1999). The oxygen consumption and ammonia production of juvenile pikeperch and perch (BW of approximately 20 g) were 285 and 330 mg $O_2$ $kg^{-1}$ $h^{-1}$ and 17.7 and 22.0 mg TAN $kg^{-1}$ $h^{-1}$, respectively. The mean daily values of perch OC and AE were comparable to the maximum daily values of these parameters confirmed in pikeperch. As the fish grew, these differences gradually became less evident – pikeperch and perch OC and AE of approximately 55 g were 205 and 215 mg $O_2$ $kg^{-1}$ $h^{-1}$ and 7.3 and 8.3 mg TAN $kg^{-1}$ $h^{-1}$, respectively.

Daily variations in oxygen consumption (difference between the maximum and minimum OC values confirmed in a given daily cycle of measurements – $OC_{max}$ and $OC_{min}$) ranged from 43.7 mg $O_2$ $kg^{-1}$ $h^{-1}$ (Group V) to 112.6 mg $O_2$ $kg^{-1}$ $h^{-1}$ (Group II), and ammonia excretion (differences between $AE_{max}$ and $AE_{min}$) from 6.3 mg TAN $kg^{-1}$ $h^{-1}$ (Groups V and VI) to 15.8 mg TAN $kg^{-1}$ $h^{-1}$ (Group II). In practice, the daily variation in these parameters was determined by the quotient of the maximum and mean values ($OC_{max}/OC_{mean}$ and $AE_{max}/AE_{mean}$; Colt and Orwicz 1991). In the current study, OC variation expressed in this way ranged from 1.10 to 1.19, and was within the range determined often under cultivation conditions for various fish species (Colt and Orwicz 1991). Daily fluctuation of AE was higher and ranged from 1.30 to 1.54 (Table 2). It is worth emphasizing that feeding frequency has a substantial impact on the values of the $OC_{max}/OC_{mean}$ and $AE_{max}/AE_{mean}$ quotients. This is why similar values of these parameters can be obtained using continuous feeding, as in the current study, throughout the course of the day.

Since the studies of perch metabolism were conducted under cultivation conditions (rearing on a semi-commercial scale) and at the optimal water temperature, the results presented here regarding oxygen requirements and ammonia excretion are largely utilitarian. They do, however, refer to juvenile stages with body weights exceeding 18 g. It is recommended that analogous metabolic measurements are taken of fish with body weights that are less than those in the current study. It is also known that many other factors impact fish metabolism, including the ration and chemical composition of feed and water temperature (Jobling 1994). With the aim of developing a feeding schedule for this species, it will be necessary to conduct investigations of the impact these parameters have on the metabolism of the Eurasian perch.

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# STRESZCZENIE

KONSUMPCJA TLENU I WYDALANIE AMONIAKU PRZEZ OKONIA (*PERCA FLUVIATILIS* L.) PODCHOWYWANEGO W OPTYMALNYCH WARUNKACH TERMICZNYCH

Celem pracy było określenie konsumpcji tlenu (OC, mg $O_2$ $kg^{-1}$ $h^{-1}$) i produkcji amoniaku (AE, mg TAN $kg^{-1}$ $h^{-1}$) przez okonia podchowywanego w obiegu recyrkulacyjnym, w optymalnej temperaturze wzrostu tego gatunku, tj. 23°C. Badania prowadzono w trakcie intensywnego tuczu okonia na paszy sztucznej. Całodobowe pomiary tempa metabolizmu przeprowadzono dla sześciu grup wielkości ryb (średnia masa ciała (BW) w poszczególnych grupach wynosiła: 18,4, 30,7, 46,4, 56,5, 67,8, 82,3 g; tab. 1). W badanym przedziale wielkości okonia OC obniżyła się od 336,2 do 185,0 mg $O_2$ $kg^{-1}$ $h^{-1}$, a AE od 22,0 do 5,6 mg TAN $kg^{-1}$ $h^{-1}$. Przyrost masy ciała o 1 g przyczyniał się do obniżenia konsumpcji tlenu średnio o 2,53 mg $O_2$ $kg^{-1}$ $h^{-1}$, a wydalania amoniaku o 0,28 mg TAN $kg^{-1}$ $h^{-1}$ (tab. 2). W analizowanym zakresie masy ciała okonia, arytmetyczne zależności OC-BW oraz AE-BW miały charakter liniowy, a współczynniki determinacji $R^2$ równań regresji liniowych opisujących te związki, były wysoce istotne statystycznie i przyjęły wartość powyżej 0,9 (rys. 1).