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COMPARATIVE ANALYSIS OF RESULTS OF USING DIFFERENT FOO D RATIO NSIN JUVENILE WELS (*SILURUS GLANIS*) CUL TURE

PO RÓWNANIEEFEKTÓW CHOWU NARYBKU SUMA EUROPEJSKIEGO (SILURUS GLANIS) ŻYWION EGO RÓŻNYMI METABOLICZNYMI DAWKAMI PASZY

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Groups of "small" (65 ± 10 g/indiv.) and "large" (110 ± 10 g/indiv.) wels (*Silurus glanis*) kept for 49 days in cages in cooling water, were fed with semi-extruded feed offered in 5 different doses (1%, 1.5%, 2%, 2.5%, 3%), calculated relatively to the individual metabolic fish weight ($W^{0.8}$). The feed contained 48.5% crude protein, 14.4% lipids and 20.97 KJ/g energy brutto. The experiment showed that, at the water temperature range of 24–28°C, the daily feed demand was identical in both groups of wels and amounted to 2% $W^{0.8}$, while at 18–23°C it did not exceed 1.5% $W^{0.8}$.

INTRODUCTION

Appropriate quality of food and suitable rations are important elements of a successful intensive fish culture. The method of determining a daily food ration, used so far, which involves calculating the per cent food ration from the mean individual fish weight, raises some reservations. These stem from the fact that relationships between abiotic (e.g., water temperature) or biotic factors (e.g., fish individual weight), and the level of metabolism of a given fish are not fully known. In a homoiotherm organism, the relationship between metabolism and body mass can be described as a W^b, where W (kg) raised to the power of 0.75 is the metabolic mass unit (Kleiber 1947, 1961). The metabolic mass unit of fish, is most often expressed as $W^{0.8}$ (Winberg 1960; Paloheimo and Dickie 1965, 1966a, b; Huisman and Valentijn 1981; Hogendoorn et al. 1983; Schippers et al. 1992). As the metabolic rate of fish, and consequently their energetic needs, are proportional to their metabolic mass, it seems justified to express the optimal daily food ration in relation to the latter, rather than to calculate it from the actual individual mass.

The study described here was aimed at testing the efficacy of using the metabolic fish weight in determining the optimal daily food rations for two size classes of young European wels kept in cages in cooling water.

MATERIAL AND METHODS

The experiment was carried out between 13 August and 1 October 1993, at the Aquaculture Station located close to the Dolna Odra power station at Stare Czarnowo. The fish were kept in 0.75 × 2.0 × 0.8 m (1 m^3 working capacity) cages placed in the power station's cooling water canal. The cage walls (1.5 m^2 each) were made of 6 mm mesh size netting.

The experiment involved two groups of 4-month-old European wels, stocked at 90 indiv./cage in 30 cages (3 cages per one treatment). One group consisted of "small" wels of 65 ± 10 g mean individual weight, while the other group, "large", consisted of 110 ± 10 g mean individual weight fish. Both groups were fed the semi-extruded trout granulate (Aller Mölle 3800–903) (5 mm granule diameter). The experiment involved 5 treatments, each used in triplicate, in which the fish were offered daily food rations of 1.0%, 1.5%, 2.0%, 2.5%,and 3.0% of their metabolic weight ($kg^{0.8}$). The food was administered manually, always within 9:00–17.00 hours, identical doses being fed at 30-min. intervals. Each daily food provided was calculated from:

$$DFP = \frac{MFR \cdot n \cdot W^{0.8}}{100} \quad (1)$$

where:
DFP —Daily Food Provided (kg);
MFR —Metabolic Food Ration (%);
n —number of fish;
W —mean individual fish weight (kg).

To follow the dynamics of the basic culture indices and to adjust the amount of food offered, all the fish in a cage were weighed, to the nearest 0.05 kg, at 6–8-day intervals (the periods between weighing were regarded as stages of the experiment). The results served to calculate the *FCR* (Food Conversion Rate, i.e., the total food ration per unit of fish weight gain), *SGR* (Specific Growth Rate defined as a difference between ln of final and initial individual weight of fish divided by time), and the following retention indices: crude protein, *aNPU* (apparent Net Protein Utilization, i.e., amount of crude protein retained per unit of crude protein provided); gross energy, *ER* (Energy Retained, i.e., amount of gross energy retained per unit of gross energy provided); and lipids, *aLR* (apparent Lipids Retained, i.e., amount of lipids retained per unit of lipid provided). Additionally, the Metabolic Growth Rate (*MGR*) was calculated as:

$$MGR = \frac{MFR}{FCR} \quad (2)$$

where:
MGR —Metabolic Growth Rate ($g/kg^{0.8}$);
MFR —Metabolic Food Ration ($g/kg^{0.8}$);
FCR —Food Conversion Rate.

Statistical processing of the data involved testing for significance of differences in all the indices listed above between the treatments, using the LSD test ($P = 0.05$).

At the beginning of the experiment and at its end, 5 fish from each treatment were analysed, after homogenisation (Tecator 1094), for dry weight (drying at 105°C for 12 h), crude protein (Kjeltec 1026), lipids (Soxhlet extraction for 12 h in ethyl ether), and ash contents (combustion at 550°C for 12 h). The feed was subject to identical assays, the carbohydrate content being calculated from the difference between the dry weight and the sum of the remaining components. Brutto energy content of the feed was calculated: lipids—39.53, protein—23.63 and carbohydrates—17.15 KJ/g.

Temperature, dissolved oxygen content, and pH of the cooling water were automatically recorded at 60 min. intervals. The daily mean, maximum, and minimum values of each parameter are shown in Fig. 1.

RESULTS AND DISCUSSION

As shown by our results, the demand of the European wels for crude protein is high and amounts to about 45%, the demand for lipids being determined at about 13% (Filipiak et al. 1993c; Trzebiatowski et al. 1995). The present work involved the commercial feed manufactured by Aller Mölle the chemical composition (analysed specification) which contained: 94.0% dry matter, 48.5% crude protein, 14.4% lipids, 9.1% ash, 22.4% carbohydrates and 20.97 KJ/g gross energy of which, and the content of the basic nutrients in particular, seemed to meet the demand.

Over the period of the experiment, the dissolved oxygen content, pH, and temperature of the Dolna Odra power station cooling water ranged within 5.7–11.9 mg/dm^3; 7.4–9.1, and 16.2–29.6°C, respectively (Fig. 1). Noteworthy is the latter range, important for growth rate of poikilotherms. According to Mueller and Váradi (1980), the European wels grows fast at a temperature of 20–24°C. Wiśniewolski (1986) reported the species' thermal optimum to be higher (24–26°C), while Hilge (1985) set the optimum at 24°C. As shown by data in Fig. 1 and Tab. 1, regardless of the food ration, the highest *SGR* were obtained at the second stage of the experiment (20–27 August) when the mean daily water temperature ranged within 24–26°C. However, over most of the experimental period the water temperature was lower (not exceeding 23°C), which most likely caused an unfavourable reduction in the fish growth rate, particularly evident during the later stages of the culture.

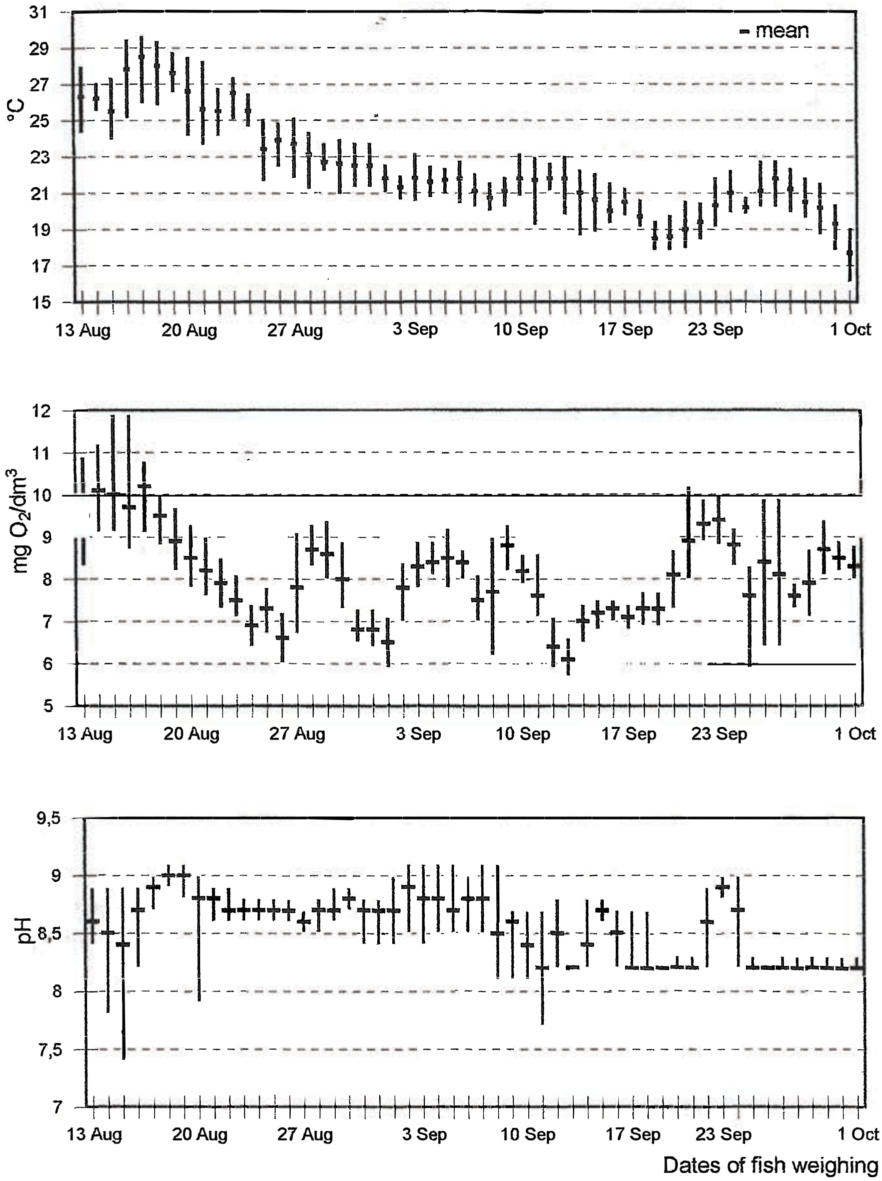

Fig. 1. Diurnal changes of temperature (A), oxygen content (B) and pH (C) in cooling water during the experiment

Table 1

Specific Growth Rate (*SGR*) of "small" and "large" European wels in each period of experiment

Food ration % $W^{0.8}$/day	Dates of fish weighing						
	20 Aug	27 Aug	3 Sep	10 Sep	17 Sep	23 Sep	1 Oct
"Small" wels	*SGR* (%/day)						
1.0	1.97^{a}	2.62^{b}	2.59^{a}	2.06^{a}	1.91^{a}	1.77^{a}	1.42^{a}
1.5	2.56^{b}	3.18^{c}	3.11^{cd}	2.43^{b}	2.32^{b}	2.38^{b}	1.86^{b}
2.0	3.35^{d}	3.52^{d}	3.14^{d}	2.45^{b}	2.30^{b}	2.34^{b}	1.90^{b}
2.5	3.32^{c}	3.56^{d}	3.10^{cd}	2.42^{b}	2.29^{b}	2.37^{b}	1.85^{b}
3.0	3.34^{c}	3.60^{d}	3.09^{cd}	2.43^{b}	2.27^{b}	2.37^{b}	1.82^{b}
"Large" wels							
1.0	1.84^{a}	2.41^{a}	2.49^{a}	2.03^{a}	1.88^{a}	1.69^{a}	1.55^{a}
1.5	2.61^{b}	3.08^{c}	3.00^{bc}	2.46^{b}	2.30^{b}	2.38^{b}	1.88^{b}
2.0	3.19^{c}	3.56^{d}	2.93^{b}	2.44^{b}	2.30^{b}	2.36^{b}	1.92^{b}
2.5	3.21^{c}	3.50^{d}	3.00^{bc}	2.42^{b}	2.27^{b}	2.36^{b}	1.84^{b}
3.0	3.27^{c}	3.54^{d}	2.97^{b}	2.43^{b}	2.29^{b}	2.37^{b}	1.83^{b}
SE	0.02	0.02	0.02	0.01	0.01	0.02	0.02

Letters accompanying figure in columns denote non-significant difference at P = 0.05
SE- standard error pooled

Table 2

Food Conversion Rate (*FCR*) of "small" and "large" European wels in each period of experiment

Food ration % $W^{0.8}$/day	Dates of fish weighing						
	20 Aug	27 Aug	3 Sep	10 Sep	17 Sep	23 Sep	1 Oct
"Small" wels	*FCR*						
1.0	0.81^{ab}	0.57^{a}	0.56^{a}	0.69^{a}	0.73^{b}	0.78^{ab}	1.05^{b}
1.5	0.90^{c}	0.68^{b}	0.67^{b}	0.84^{c}	0.86^{d}	0.84^{b}	1.07^{b}
2.0	0.90^{c}	0.81^{d}	0.88^{c}	1.11^{e}	1.14^{f}	1.10^{d}	1.42^{d}
2.5	1.15^{d}	1.01^{f}	1.12^{d}	1.41^{g}	1.45^{h}	1.41^{f}	1.80^{f}
3.0	1.35^{f}	1.18^{h}	1.33^{e}	1.66^{i}	1.73^{j}	1.67^{h}	2.17^{g}
"Large" wels							
1.0	0.78^{a}	0.57^{a}	0.53^{a}	0.64^{a}	0.68^{a}	0.75^{a}	0.87^{a}
1.5	0.81^{ab}	0.65^{b}	0.64^{b}	0.77^{b}	0.80^{c}	0.77^{ab}	0.97^{ab}
2.0	0.87^{bc}	0.73^{c}	0.87^{c}	1.02^{d}	1.05^{e}	1.00^{e}	1.29^{c}
2.5	1.09^{d}	0.94^{e}	1.07^{d}	1.29^{f}	1.34^{g}	1.30^{e}	1.62^{e}
3.0	1.26^{e}	1.10^{g}	1.28^{e}	1.53^{h}	1.57^{i}	1.53^{g}	1.91^{f}
SE	0.01	0.01	0.01	0.01	0.01	0.01	0.02

See Tab. 1

The data in Tab. 1 show that during the initial two stages of the culture (13–27 August), the *SGR* clearly increased in both groups when the daily ration was increased from 1% to 2%. On the other hand, metabolic rations higher than 2% resulted only in a significant increase of the food conversion rate (Tab. 2), the *SGR* remaining almost unchanged (differences statistically non-significant). That means that during the period of a high daily mean temperature (24–28°C), the optimal ration did not exceed 2% metabolic fish weight. During the third and subsequent stages of the experiment, similarly to the second stage, the lowest *SGR* and *FCR* values were obtained when both groups were fed a 1% food ration. In comparison, the fish offered a 1.5% ration showed a significantly higher relative growth rate. The lack of statistically significant differences in *SGR* between the fish fed that ration and the remaining ones means that the wels demand for food became at that time reduced down to 1.5% metabolic weight.

It is generally known that the amount of energy a fish uses is closely related to both its mass and to the water temperature. The daily energy intake (KJ/kg) decreases with increasing body weight (Jobling 1994). If, however, the metabolic weight, instead of the individual body weight, is used in calculations, the individual metabolic energy intake ($KJ/kg^{0.8}$), and consequently the necessary food intake ($g/kg^{0.8}$) should be constant. Thus the reduction in food demand from 2% to 1.5% $W^{0.8}$ should have been affected by a change in water temperature rather than by the increasing individual body weight of the fish. A 10°C increase in water temperature increases fish metabolic rate by a factor of 1.65–2.7 and conversely, every decrease in water temperature results in the metabolism being slowed down (Jobling 1994). As shown by the data in Fig. 1, as of the third stage of the experiment, the water temperature decreased from 23 to 17°C, that is much below the level regarded as optimal for the growth of the European wels. In consequence, the food demand became reduced; regardless of the ration used, an increase in food conversion rate was recorded (Tab. 2). A similar, cooling water temperature-affected dynamics of the culture indices studied was recorded also in the African catfish: a slight temperature reduction (below the optimum of 25°C) resulted in a rather rapid decrease in the growth rate, associated with poorer food utilisation (Filipiak et al. 1993a, b).

It should be stressed that at every stage of the experiment, the 1.5–2.0% food rations resulted in very low (not exceeding 1) values of food conversion rate (Tab. 2). The reason should be sought not only in the appropriate quality and quantity of food, but also in a specific behaviour of the wels: apart from feeding times, the fish stayed immobile on the bottom of their cages and showed no apparent locomotory activity.

During most stages of the experiment, differences between the two size classes (fed with identical food rations) in their *SGR* values were non-significant (Tab. 1). However, it is well known that the fish growth rate (expressed as, e.g., % or %/day) decreases with increasing individual body weight. Therefore it would be logical to expect *SGR* values of the "large" fish to be lower than that of the "small" fish. The situation in which fish individuals differing widely in their body weight attain identical or very similar values of *SGR* over the same period of time indirectly suggests differences in their growth potential. To determine those differences, the metabolic growth rate (*MGR*) was introduced whereby the fish growth was determined as g/day kg$^{0.8}$ (formula 2). When introducing *MGR*, the authors assumed that, should food rations be calculated respectively to the metabolic body weight, the fish growth rate ought to be related to that weight as well. As shown by data in Tab. 3, at most stages of the experiment, when fed identical food rations, the "large" fish had clearly higher *MGR*s than the "small" wels, which was not the case with respect to *SGR*. That means that *MGR* is a better comparative measure of growth rate than *SGR* as it allowed to find out that the "large" fish had a higher growth potential. That conclusion was confirmed also by the final *MGR* values (Tab. 4). Noteworthy is also the fact that at metabolic food rations higher that 2% $W^{0.8}$ no significant differences between the final *MGR* values were found (similarly to the lack of differences between the values of *SGR*). The feeding behaviour and low motoric activity of the European wels resulted in its food demand, as calculated relative to the metabolic body weight, being low, not exceeding 2% $W^{0.8}$. A similar level of food demand was found in carp (Omar and Gunther 1987), and in African catfish (Sadowski and Trzebiatowski 1995), while an even lower level (1.5% $W^{0.8}$) was revealed in the Nile tilapia (Filipiak et al. 1995).

Table 3

Metabolic Growth Rate (*MGR*) of "small" and "large" European wels in each period of experiment

Food ration % $W^{0.8}$/day	Dates of fish weighing						
	20 Aug	27 Aug	3 Sep	10 Sep	17 Sep	23 Sep	1 Oct
"Small" wels	*MGR* (g/kg$^{0.8}$·day)						
1.0	12.44^{a}	17.42^{a}	17.89^{a}	14.47^{a}	13.69^{a}	12.84^{a}	9.50^{a}
1.5	16.61^{b}	21.93^{b}	22.34^{bc}	17.76^{c}	17.52^{c}	17.86^{b}	14.03^{c}
2.0	22.23^{d}	24.63^{d}	22.77^{bcd}	18.10^{c}	17.52^{c}	18.21^{bc}	14.09^{c}
2.5	21.82^{d}	24.73^{d}	22.29^{b}	17.69^{c}	17.26^{c}	17.72^{b}	13.88^{c}
3.0	22.23^{d}	25.40^{de}	22.51^{bcd}	18.07^{c}	17.37^{c}	18.05^{b}	13.86^{c}
"Large" wels							
1.0	12.81^{a}	17.53^{a}	18.78^{a}	15.64^{b}	14.77^{b}	13.42^{a}	11.51^{b}
1.5	18.56^{c}	23.09^{c}	23.37^{cd}	19.58^{d}	18.83^{d}	19.41^{de}	15.42^{d}
2.0	23.03^{de}	27.28^{f}	23.10^{bcd}	19.68^{d}	19.11^{d}	20.01^{e}	15.51^{d}
2.5	22.99^{de}	26.50^{ef}	23.42^{d}	19.32^{d}	18.65^{d}	19.25^{cde}	15.51^{d}
3.0	23.80^{e}	27.30^{f}	23.51^{d}	19.65^{d}	19.12^{d}	19.62^{e}	15.69^{d}
SE	0.13	0.11	0.10	0.07	0.06	0.10	0.09

See Tab. 1

The comparison of final results obtained for the "small" and "large" fish shows that, regardless of the food ration, the "large" wels produced significantly higher values of crude protein, lipid, and energy retention. The differences between the size groups should be explained not by (small) differences in the body contents of crude protein and lipids, but rather by the clearly lower level of food intake per unit weight gain in the "large" fish

(Tab. 4, 5). The relatively high values of *aNPU*, *aLR*, and *ER*, obtained with the optimal food rations (1.5–2% $W^{0.8}$) are typical not only of the European wels, but also of other fish species cultured in cooling water, such as the Nile tilapia (Filipiak et al. 1995), African catfish (Filipiak et al. 1993 b, c; Sadowski and Trzebiatowski 1995), and carp (unpubl. data). It is obvious that a sufficiently high level of nutrient retention in a fish body depends mostly on the feed used, appropriate for a species in terms of quality and quantity. The results of this experiment and of those reported in the literature and these ones referred to, demonstrate that calculation of daily food ration relative to the fish metabolic body weight can be one of more rational approaches to improving fish culture technology.

Table 4

Mean body weight, Specific Growth Rate (*SGR*), Metabolic Growth Rate (*MGR*) Food Conversion Rate (*FCR*), apparent Net Protein Utilisation (*aNPU*), apparent Lipids Retained (*aLR*), Energy Retained (*ER*) of "small" and "large" European wels at the end of experiment

Food ration %$W^{0.8}$/day	Mean individual Weight of fish g initial	final	*SGR* %/day	*MGR* g/kg$^{0.8}$·day	*FCR*	*aNPU* %	*ER* %	*aLR* %
"Small" wels								
1.0	71	194	2.04^{a}	13.54^{a}	0.74^{b}	41.4^{i}	39.2^{i}	48.0^{h}
1.5	74	256	2.54^{b}	17.72^{c}	0.85^{d}	36.1^{g}	34.2^{g}	46.5^{g}
2.0	71	266	2.71^{c}	18.60^{d}	1.08^{f}	28.6^{e}	27.6^{e}	39.7^{e}
2.5	68	254	2.69^{c}	18.30^{d}	1.37^{h}	22.5^{c}	21.9^{c}	31.7^{c}
3.0	73	272	2.69^{c}	18.54^{d}	1.62^{j}	19.1^{a}	18.5^{a}	26.9^{a}
"Large" wels								
1.0	117	309	1.98^{a}	14.58^{b}	0.69^{a}	45.6^{j}	42.2^{j}	49.2^{i}
1.5	113	389	2.52^{b}	19.17^{e}	0.78^{c}	40.0^{h}	37.6^{h}	50.8^{j}
2.0	111	413	2.68^{c}	20.17^{f}	0.99^{e}	31.6^{f}	30.7^{f}	44.6^{f}
2.5	107	390	2.65^{c}	19.81^{f}	1.26^{g}	24.9^{d}	24.3^{d}	35.6^{d}
3.0	115	423	2.67^{c}	20.18^{f}	1.49^{i}	21.0^{b}	20.5^{b}	30.1^{b}
SE			0.01	0.05	0.01	0.07	0.06	0.05

See Tab. 1

CONCLUSION

The experiment showed that, at a the water temperature range of 24–28°C, the daily feed demand was identical in both groups of juvenile wels ("small" and "large" weight) and amounted to 2% $W^{0.8}$, while at 18–23°C it did not exceed 1.5% $W^{0.8}$.

Table 5

Chemical composition of "small" and "large" European wels at the start and at the end of experiment (%)

Food ration $\%W^{0.8}$/day	Dry matter	Crude protein	Lipids	Ash
	„Small" wels—start of experiment			
	24.12	14.80	7.45	1.75
	„Small" wels—end of experiment			
1.0	23.08[a]	14.83[a]	5.97[a]	2.17[a]
1.5	23.17[a]	14.81[a]	6.18[a]	2.12[a]
2.0	23.69[b]	14.89[a]	6.48[b]	2.13[a]
2.5	23.61[b]	14.87[a]	6.55[b]	2.13[a]
3.0	23.72[b]	14.92[a]	6.57[b]	2.12[a]
SE	0.02	0.02	0.04	0.01
	„Large" wels—start of experiment			
	24.32	15.06	7.20	1.85
	„Large" wels—end of experiment			
1.0	23.09[a]	15.13[a]	5.75[a]	2.13[a]
1.5	24.00[b]	15.15[a]	6.15[b]	2.13[a]
2.0	24.00[b]	15.18[a]	6.58[c]	2.15[a]
2.5	23.96[b]	15.18[a]	6.66[c]	2.13[a]
3.0	23.98[b]	15.14[a]	6.64[c]	2.12[a]
SE	0.03	0.02	0.03	0.01

See Tab. 1

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PORÓWNANIE EFEKTÓW CHOWU NARYBKU SUMA EUROPEJSKIEGO (*SILURUS GLANIS*) ŻYWIONEGO RÓŻNYMI METABOLICZNYMI DAWKAMI PASZY

STRESZCZENIE

Celem badań było praktyczne sprawdzenie efektywności stosowania parametru metabolicznej masy ryby ($W^{0.8}$) w określaniu racjonalnej dziennej dawki paszy dla różnych wielkości 4-miesięcznego narybku suma europejskiego hodowanego w sadzach w wodzie pochłodniczej. Doświadczenie wykonano w okresie 13.08–1.10. 1993 r. w Rybackiej Stacji Doświadczalnej (RSD) Zakładu Akwakultury Akademii Rolniczej w Szczecinie, usytuowanej przy elektrowni „Dolna Odra" w Nowym Czarnowie. Dwie grupy sumów („małe" — o masie 65 g/szt. oraz „duże" — 110 g/szt.) w obsadzie 90 szt./sadz, żywiono semi-ekstrudowaną duńską paszą Aller Mölle 3800–903, zawierającą m.in. 48,5% białka ogólnego, 14,4% lipidów oraz 20,97 KJ/g energii brutto. Dla każdej z obydwu grup wielkościowych sumów paszę zadawano codziennie (od 9^{00} do 16^{00}) w dawkach wynoszących: 1,0%, 1,5%, 2,0%, 2,5%, 3,0% metabolicznej masy ryby ($kg^{0.8}$). Z porównania rezultatów chowu uzyskanych na sumach „małych" i „dużych" wynika, że niezależnie od wielkości dawki paszy ta ostatnia grupa ryb charakteryzowała się większymi wskaźnikami retencji białka ogólnego jak również retencji lipidów i energii brutto. Przyczynę tego należy upatrywać nie tyle w różnicach zawartości białka ogólnego i lipidów w ciele obydwu grup ryb, które były niewielkie lecz w wyraźnie mniejszym poziomie zużycia paszy na jednostkę przyrostu masy sumów „dużych". Doświadczenie wykazało, że w okresie, w którym temperatura wody pochłodniczej mieściła się w zakresie 24–27°C, optymalna „metaboliczna" dawka paszy dla obydwu grup wielkościowych narybku suma była jednakowa i wyniosła 2% $W^{0.8}$, natomiast w zakresie 18–23°C — dzienna wielkość tej dawki przekraczała 1,5% $W^{0.8}$. Na podkreślenie zasługuje fakt, że we wszystkich etapach doświadczenia (kontrolne ważenia wszystkich ryb przeprowadzano co 6–8 dni) w efekcie zadawania paszy w optymalnych dawkach uzyskano bardzo małe (poniżej 1) współczynniki pokarmowe. Przyczynę tego należy upatrywać nie tylko w doborze odpowiedniej dla tych ryb jakości i ilości paszy, lecz również (a może przede wszystkim) w specyficznym zachowaniu się sumów, które, jak zaobserwowano we wszystkich wariantach, poza krótkimi kilkuminutowymi okresami aktywności ruchowej w momencie zadawania paszy, przez większość dnia leżały nieruchomo na dnie sadzów.

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