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RESEARCH ARTICLE

Slaughter yield and growth performance indexes of pikeperch (*Sander lucioperca* (L.)) selects reared in recirculating aquaculture systems at suboptimal temperatures

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Abstract. The aim of the study was to determine the impact diet has on the basic growth performance indexes and slaughter yield of pikeperch selects (body weight > 1.35 kg). Tagging the individual fish with PIT tags also permitted determining the impact of sex on the studied growth performance indexes. The fish were fed two diets with protein/fat/carbohydrate ratios of 50.5/11.8/29.4 in group I and 47.1/14.1/29.0 in group II. Neither the diets nor the sex of the fish has a significant impact on the final body weight or condition of the pikeperch ($P > 0.05$). Significant differences were noted between the relative indicators of pikeperch growth performance (SGR and DGR) (impact of diet and sex; $P < 0.05$). Among the growth performance indexes analyzed, e.g., viscerosomatic (VSI), hepatosomatic (HSI), and gonadosomatic (GSI), statistically significant differences were noted with regard to HSI (impact of diet and sex) and GSI (impact of sex) ($P < 0.05$). The analysis of the relative values of the pikeperch body parts studied (expressed in % body weight) indicated that the studied parameters had significant impacts on the slaughter yield of the viscera (impact of sex) and skin (impact of diet), as well as on gutted whole fish, gutted and headed whole fish, fillets with skin, and skinned fillets (impact of sex) ($P < 0.05$). The slaughter yields of the skinned fillets of males from both dietary treatments were approximately 5% higher than those of the females.

Keywords: recirculating aquaculture systems, sex, pikeperch, slaughter yield, feeding

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Introduction

Introducing new species to aquaculture is one sign that this sector is developing (Bilio 2007). One of the new groups of fish that are promising is the percids, which includes pikeperch, *Sander lucioperca* (L.). Particularly promising is the intensive propagation of this species in recirculating aquaculture systems (RAS) (Philipsen 2008, FAO 2012). Propagation methods in RAS are still in the developmental stages, and knowledge about artificial reproduction and intensive pikeperch production remains incomplete (Kestemont and Mélard 2000, Zakęś and Demska-Zakęś 2009, FAO 2012). Scientific study focuses considerable attention on the nutritional requirements of pikeperch. Tests of diets are performed primarily on the juvenile stages of this species (Zakęś et al. 2004, Nyina-Wamwiza et al. 2005, Rónyai and Csengeri 2008, Schulz et al. 2008, Wang et al. 2009). There is a dearth of information regarding the indexes and growth performance of pikeperch reared in RAS in the final, commercial size category, i.e., fish for consumption (body weight 1-2 kg).

Feeding the fish high-energy feeds has a significant impact on many physiological processes and can determine, for example, the proximate composition of the meat and the values of indicators describing slaughter yield (Jobling 2001). The energy value of natural feed, which ranges from detritus to fish, is several to approximately thirty times lower than that of formulated diets: for example, the energy value of molluscs and zooplankton is 3.0-4.5 kJ g^{-1} and for fish it is 5.5-7.5 kJ g^{-1}, but formulated feed often exceeds 20 kJ g^{-1} (Jobling 1994). Depending on the species, fish store excess energy in different organs or tissues, including in the peri-intestinal cavity, the liver, and in muscle or connective tissues (skin and bones) (Jobling 2001). Percids store most excess energy in the viscera (Mathis et al. 2003, Boujard et al. 2004, Mairesse et al. 2005). Fat deposition in the body cavity can result in lowered slaughter yields (Jobling et al. 1998, Jobling 2001), because the fat is removed when the fish is gutted during initial processing, and this can determine profitability.

The aim of the current study was to determine the impact of pikeperch select (body weight > 1.35 kg) diets on basic growth performance indexes and the slaughter yield. Individually tagging the fish with PIT tags also permitted determining the impact the sex of the fish had on the rearing results studied.

Materials and methods

The experimental material was obtained from out-of-season reproduction of cultivated pikeperch spawners held in RAS (Zakęś 2007). Larval and juvenile stages were reared in RAS on commercial formulated trout feed (Zakęś 2009). After 24 months of rearing in RAS, 56 pikeperch selects (28 females and 28 males; mean body weight approximately 1 kg). The sex of the fish was determined with a catheter (Zakęś and Demska-Zakęś 2009). The fish were marked individually with passive integrated transponder (PIT) tags (Fish Eagle, Lechlade, Great Britain). The intraperitoneal method was used to implant the tags (Hopko et al. 2010). The fish were stocked into one rearing tank that was part of a RAS and reared for the subsequent four months. After this period, when the fish were 28 months old, they were divided into two experimental groups of 28 specimens per group of 14 females and 14 males. The initial mean body weight of the fish was about 1.35 kg, and the stock biomass was about 20 kg m^{-3}. The groups of fish were placed in separate tanks (2 × 2 × 0.8 m (L × W × H)) that were part of a RAS, and fed two different 8 mm granulated feeds for 109 days. Group I was fed feed with a protein/fat/carbohydrate ratio of 50.5/11.8/29.4, while that of group II was 47.1/14.1/29.0 (Table 1).

Table 1

Proximate composition of tested diets (g kg^{-1} wet weight)

Components	Tested diet: diet I	diet II
Total protein	505	471
Raw fat	118	141
Nitrogen-Free Extract – NFE*	294	290
Fiber	21	8
Ash	62	90
Gross energy (MJ kg^{-1} feed)	21.29	20.69

*NFE = 1000 – (total protein + raw fat + fiber+ash)

The proximate composition of the feed, i.e., the total protein was determined with the Kjeldahl method and a conversion factor of 6.25; the raw fat content was determined with the Soxhlet method with petroleum ether as the solvent; raw ash was determined by mineralizing the samples at a temperature of 600°C (AOAC 1990). The fish were fed for 12 h d^{-1} (19.00-07.00) with an automatic band feeder (4305

FIAP, Fishtechnic Gmbh, Germany). The daily feed ration was 60-50 g kg^{-1} stocking biomass.

During the rearing period, the water quality parameters were monitored weekly. Water temperature was 21.2 ± 1.7°C. Oxygen concentration at the tank outflows did not fall below 5.8 mg l^{-1}, the total ammonia nitrogen concentration (TAN = NH_4^+-N + NH_3-N) was below 0.12 mg TAN l^{-1}, and water pH ranged from 7.1 to 7.5. A constant, daily photoperiod of 24L:0D was maintained with artificial light, and the light intensity measured at the surface of the tanks was within a range of 10-20 lx.

At the end of rearing the individual specimens were identified by their PIT tags. The fish were anesthetized in an aqueous solution of etomidate at a dose of 1.5 ml l^{-1} (Propiscin; IFI Olsztyn, Poland; Kazuń and Siwicki 2001), and then weighed (BW ± 1 g) and measured (body length SL and total length TL ± 1 mm). These data were used to calculate the following growth performance indexes: specific growth rate SGR (%) = 100 × (ln final BW (g) – ln initial BW (g)) × rearing $time^{-1}$ (days), daily growth rate DGR (g d^{-1}) = (final BW (g) – initial BW (g)) × rearing $time^{-1}$ (days), condition coefficient K = 100 × (BW × SL^{-3}), feed conversion ratio FCR = weight of feed fed (g) × fish biomass $growth^{-1}$ (g).

Ten specimens from each group were collected (group I – 6 females + 4 males, group II – 5 females + 5 males). After anesthetizing these individuals (3 ml etomidate l^{-1}), they were euthanized by decapitation. After dissecting them, heading with a simple cut, cutting off the fins, and skinning the fillets, the peri-intestinal fat + gastrointestinal tract, liver, gonads, head, fins, gutted whole fish, spine with ribs, fillet with skin, skin, and skinned fillets were weighed to the nearest ± 0.1 g. The body weight of the whole fish and the weight of the various parts of each specimen, the slaughter yield was determined after gutting, heading, filleting, and skinning the fillets. The percentage share of the viscera (peri-intestinal fat + gastrointestinal tract + gonads + liver), head, spine and fins, and skin with regard to the total BW were determined. The following indexes were also calculated: viscerosomatic VSI (%) = 100 × (peri-intestinal fat and gastrointestinal tract (g) × BW^{-1} (g)), hepatosomatic, HSI (%) = 100 × (liver weight (g) × BW^{-1} (g)) and the gonadosomatic GSI (%) = 100 × (gonad weight (g) × BW^{-1} (g)).

The data were analyzed with Statistica 8.0 (StatSoft, Inc., USA). Homogeneity of variance was checked with Levene's test. Percentage data were transformed with the *arcsin* function. Further analysis was performed with two-way analysis of variance MANOVA (diet type (D) × sex of fish (S)). Differences between the groups were considered statistically significant at $P \leq 0.05$.

Results

Neither the diets tested nor sex had a significant impact on final pikeperch body weight or condition ($P > 0.05$; Table 2). Significant differences were noted between the relative values of the pikeperch growth performance indexes (SGR and DGR; impact of diet and sex; $P < 0.05$). The growth rate of the fish from group I was significantly higher than that noted in group II, and in both of these dietary treatment groups the values of these indexes were higher for the females. The final fish length SL and TL was significantly determined by the diet applied. Sex was also noted to have a significant impact on these indexes. The females were significantly longer than the males in both dietary treatment groups ($P < 0.05$; Table 2). Among the coefficients analyzed, i.e., VSI, HSI, GSI, significant differences were noted with regard to HSI (impact of diet and sex) and GSI (impact of sex) ($P < 0.05$; Table 2). No statistically significant interactions were noted between the tested factors, i.e., the diets and pikeperch sex, with regard to any of the growth performance indexes analyzed ($P > 0.05$).

Among the analyzed body parts, significant differences were only noted in viscera weight (impact of sex) ($P < 0.05$; Table 3). In subsequent stages of processing, i.e., gutted whole fish, gutted and headed whole fish, fillets with skin, and skinned fillets, pikeperch weight was not determined by diet or sex ($P > 0.05$). The analysis of the relative values of the pikeperch body parts studied (expressed in % body

Table 2
Rearing indexes of pikeperch selects fed two different commercial feeds (mean values (± SD))

Index	Group I			Group II			MANOVA, value of P		
	females (n = 14)	males (n = 14)	together (n = 28)	females (n = 14)	males (n = 14)	together (n = 28)	S × D	sex (S)	diet (D)
Initial body weight (kg)	1.32 (± 0.23)	1.37 (± 0.28)	1.35 (± 0.25)	1.39 (± 0.18)	1.33 (± 0.24	1.36 (± 0.21)	> 0.05	> 0.05	> 0.05
Final body weight (kg)	2.05 (± 0.32)	1.98 (± 0.39)	2.02 (± 0.35)	2.05 (± 0.33)	1.82 (± 0.34)	1.93 (± 0.35)	> 0.05	> 0.05	> 0.05
Body length SL (cm)	55.3 (± 2.6)	53.8 (± 2.9)	54.6 (± 2.8)	54.6 (± 2.2)	52.0 (± 2.5)	53.2 (± 2.7)	> 0.05	< 0.05	< 0.05
Total length TL (cm)	61.0 (± 2.8)	59.5 (± 3.0)	60.3 (± 2.9)	59.9 (± 2.4)	57.2 (± 2.6)	58.4 (± 2.8)	> 0.05	< 0.05	< 0.05
Specific growth rate SGR (%)	0.41 (± 0.05)	0.34 (± 0.06)	0.37 (± 0.06)	0.35 (± 0.04)	0.29 (± 0.08)	0.32 (± 0.07)	> 0.05	< 0.05	< 0.05
Daily growth rate DGR (g d^{-1})	6.70 (± 1.18)	5.59 (± 1.36)	6.15 (± 1.38)	6.08 (±1.47)	4.49 (± 1.56)	5.22 (± 1.70)	> 0.05	< 0.05	< 0.05
Condition coefficient (K)	1.21 (± 0.12)	1.26 (± 0.11)	1.23 (± 0.12)	1.26 (± 0.10)	1.28 (± 0.09)	1.27 (± 0.10)	> 0.05	> 0.05	> 0.05
Viscerosomatic index VSI (%)*	5.0 (± 1.3)	5.8 (± 1.3)	5.3 (± 1.3)	4.9 (± 1.0)	5.2 (± 1.3)	5.1 (± 1.1)	> 0.05	> 0.05	> 0.05
Hepatosomatic index HSI (%)*	1.8 (± 0.3)	1.4 (± 0.4)	1.6 (± 0.3)	1.4 (± 0.3)	1.2 (± 0.1)	1.3 (± 0.3)	> 0.05	< 0.05	< 0.05
Gonadosomatic index GSI (%)*	6.6 (± 0.9)	0.5 (± 0.1)	4.2 (± 3.2)	7.3 (± 1.0)	0.6 (± 0.3)	4.0 (± 3.6)	> 0.05	< 0.05	> 0.05
Feed conversion ratio FCR			1.29			1.54			

*number of fish in groups n = 10 (group I – females n=6, males n= 4; group II – females n=5, males n=5)

Table 3
Absolute values (g) of slaughter yield of pikeperch selects (mean values (± SD))

Index	Group I			Group II			MANOVA, value of P		
	females (n = 6)	males (n = 4)	together (n = 10)	females (n = 5)	males (n = 5)	together (n = 10)	S × D	Sex (S)	Diet (D)
Body weight	2148.8 (± 440.3)	1821.0 (±532.5)	2017.8 (± 480.5)	1910.8 (± 315.2)	1820.4 (± 499.1)	1865.6 (± 396.4)	> 0.05	> 0.05	> 0.05
Viscera*	294.2 (± 71.5)	155.0 (± 66.4)	238.5 (± 97.4)	271.0 (± 76.5)	140.0 (± 53.6)	205.5 (± 92.9)	> 0.05	< 0.05	> 0.05
Head	485.3 (± 96.7)	401.5 (± 135.9)	451.8 (± 115.0)	415.4 (± 87.4)	413.8 (± 112.6)	414.6 (± 95.0)	> 0.05	> 0.05	> 0.05
Spine + fins	232.8 (± 37.5)	207.0 (± 57.3)	222.5 (± 45.3)	204.4 (± 31.9)	195.8 (± 42.5)	200.1 (± 35.7)	> 0.05	> 0.05	> 0.05
Skin	216.5 (± 32.7)	185.0 (± 57.1)	203.9 (± 44.1)	183.0 (± 30.8)	173.2 (± 45.1)	178.1 (± 36.8)	> 0.05	> 0.05	> 0.05
Gutted whole fish	1828.8 (± 366.2)	1647.5 (± 456.5)	1756.3 (± 390.8)	1615.8 (± 238.4)	1663.6 (± 436.6)	1639.7 (± 332.6)	> 0.05	> 0.05	> 0.05
Gutted and headed whole fish	1341.2 (± 273.5)	1244.5 (± 320.2)	1302.5 (± 279.9)	1199.0 (± 154.2)	1247.6 (± 323.3)	1223.3 (± 240.2)	> 0.05	> 0.05	> 0.05
Fillet with skin	1097.8 (± 238.8)	1019.5 (± 260.5)	1066.5 (± 222.5)	986.4 (± 125.4)	1042.0 (± 279.4)	1014.2 (± 206.3)	> 0.05	> 0.05	> 0.05
Skinned fillet	868.0 (± 206.0)	822.5 (± 202.8)	849.8 (± 194.6)	787.4 (± 94.6)	856.0 (± 231.9)	821.7 (±170.8)	> 0.05	> 0.05	> 0.05
Losses	26.2 (± 10.80)	31.5 (± 11.5)	28.3 (± 10.8)	25.6 (± 3.6)	24.8 (± 14.7)	25.2 (± 10.1)	> 0.05	> 0.05	> 0.05

* weight of fat in the peri-intestinal cavity, gastrointestinal tract, gonads, and liver

weight) indicated that the studied parameters had significant impacts on the slaughter yield of the viscera (impact of sex) and skin (impact of diet), as well as on gutted whole fish, gutted and headed whole fish, fillets with skin, and skinned fillets (impact of sex) ($P < 0.05$; Table 4). The slaughter yields of the skinned fillets of males from both dietary treatments were approximately 5% higher than those of the females.

Discussion

During the nearly four-month-long rearing period, pikeperch weight increased by a mean of approximately 50% (from 1.35 to approximately 2.0 kg). The growth potential of the fish reared in this experiment was higher, because the optimal water temperature for growth in this species was not applied. This temperature is within the range of 25-28°C (Rónyai and Csengeri 2008, Wang et al. 2009). The mean temperature of 21.2°C applied in the current study resulted from the fact that the stock was to be used for out-of-season reproduction after later environmental and hormonal stimulation (Zakęś 2007). On-growing that is too intense does not have a positive impact on the reproductive effectiveness of this species (Z. Zakęś, unpublished data).

Feeding the pikeperch selects the tested diets did not impact the final body weight. No significant differences were noted between the body weights of males and females. However, significant differences in final length TL and SL were linked to both diet and sex. The fish fed the diet with a higher protein content were longer, and in the dietary treatment groups compared the females attained longer lengths than did the males. These differences did not have a significant impact on the value of the condition coefficient. In the current study the values were higher than in the wild (caught in lakes) and cultured pikeperch (reared in a RAS) in other studies (BW approximately 1 kg fish $^{-1}$; Jankowska et al. 2003b). The lack of differences in the final BW and the condition of the pikeperch can result from the protein contents in the diets which were in the

Table 4

Relative values (% body weight) of slaughter yield of pikeperch selects (mean values (± SD))

	Group I			Group II			MANOVA, value of P		
Index	females (n = 6)	males (n = 4)	together (n = 10)	females (n = 5)	males (n = 5)	together (n = 10)	S × D	Sex (S)	Diet (D)
Viscera*	13.8 (± 1.0)	8.3 (± 1.5)	11.6 (± 3.0)	14.2 (± 2.2)	7.6 (± 1.0)	10.9 (± 3.8)	> 0.05	< 0.05	> 0.05
Head	22.9 (± 0.9)	22.1 (± 1.0)	22.6 (± 0.9)	21.9 (± 1.7)	22.9 (± 0.1)	22.4 (± 1.3)	> 0.05	> 0.05	> 0.05
Spine + fins	11.1 (± 0.9)	11.5 (± 0.4)	11.2 (± 0.7)	10.9 (± 0.5)	11.0 (± 0.8)	10.9 (± 0.6)	> 0.05	> 0.05	> 0.05
Skin	10.3 (± 0.6)	10.2 (± 0.5)	10.3 (± 0.5)	9.7 (± 0.5)	9.6 (± 0.8)	9.7 (± 0.6)	> 0.05	> 0.05	< 0.05
Gutted whole fish	86.2 (± 1.0)	91.6 (± 1.5)	88.4 (± 3.0)	85.8 (± 2.2)	92.4 (± 1.0)	89.1 (± 3.8)	> 0.05	< 0.05	> 0.05
Gutted and headed whole fish	63.2 (± 1.5)	64.5 (± 2.2)	67.7 (± 3.7)	63.9 (± 2.5)	69.3 (± 0.9)	66.6 (± 3.4)	> 0.05	< 0.05	> 0.05
Fillet with skin	51.6 (± 1.4)	56.9 (± 2.0)	53.8 (± 3.2)	52.6 (± 2.3)	57.8 (± 0.6)	55.2 (± 3.2)	> 0.05	< 0.05	> 0.05
Skinned fillet	40.7 (± 1.5)	46.0 (± 2.2)	42.8 (± 3.2)	42.0 (± 2.5)	47.5 (± 0.7)	44.7 (± 3.4)	> 0.05	< 0.05	> 0.05
Losses	1.3 (± 0.7)	1.8 (± 0.7)	1.5 (± 0.7)	1.4 (± 0.3)	1.4 (± 0.8)	1.4 (± 0.6)	> 0.05	> 0.05	> 0.05

*weight of fat in the peri-intestinal cavity, gastrointestinal tract, gonads, and liver range recommended for culturing pikeperch, i.e., 430-500 g kg^{-1} feed (Nyina-Wamwiza et al. 2005). This also regards the amount of fat; in the diets tested it was 118 and 140 g kg^{-1} feed, which falls within the range of values acceptable for pikeperch, a species that does not metabolize high-fat feeds (fat contents > 180 g kg^{-1} feed; Kowalska et al. 2011). The significant impact of the diets on pikeperch length SL and TL is not confirmed by data from the literature primarily because, among other reasons, the index used in diet treatment tests is usually BW, and body length is not analyzed. The fish from group I that were fed the diet with the higher protein content (505 g kg^{-1} feed) attained longer lengths. It appears that feeding pikeperch selects this type of diet results in them having more advantageous growth performance indexes. Confirmation of this can be found in the feed conversion ratio (FCR), as well as in the significantly higher index of relative growth of pikeperch BW in this dietary treatment (SGR and DGR). The SGR and DGR indexes assumed significantly higher values in females, but the absolute final BW was not significantly higher. In studies of growth rates in wild pikeperch populations sex was not found to have a significant impact on growth, although it should be added that the females in a given age group achieved larger sized than did males (M'Hetli et al. 2011, Pérez-Bote and Roso 2012).

The impact of the diets tested on the analyzed pikeperch body parts was significantly reflected only in the relative slaughter yield of the skin. Previous studies indicated that the share of skin can be significantly different and range from 5.5 to 10% of BW (Jankowska et al. 2003a, Kowalska et al. 2011; Table 5). In the current study, the impact of sex was significant. It was confirmed that the slaughter yield of gutted whole fish, gutted and headed whole fish, fillets with skin, and skinless fillets of males was higher than in females. The lower slaughter yield of the females was because of the viscera weight (gonads, peri-intestinal fat, gastrointestinal tract, and liver). In the females this accounted for approximately 11% of BW, while in males it was approximately 8% of BW. The higher weights in female viscera were linked to the values of indexes of GSI and HSI, which, in the females, assumed higher values. The fish used in the present study were sexually mature, in which case the GSI of the females is significantly higher than that of the males (M'Hetli et al. 2011). The impact of sex on HSI values is not quite as unequivocal. The HSI value of females is determined largely by the maturity stage of the gonads, and the dependence between the values of GSI and HSI is mutually proportional (M'Hetli et al. 2011). The viscera of juvenile pikeperch (BW of approximately 500 g $fish^{-1}$) fed formulate feed and held in RAS was 4.8-5.8% BW, and the HSI value was approximately 1% (Kowalska et al. 2011). The ontogenetic developmental stage has a significant impact on the weight of pikeperch viscera, and it can effectively determine slaughter in this species at the different stages of processing. Slaughter yield does depend just on the maturity stage of the fish, but it can also be determined by their feeding and other rearing factors. In reared pikeperch (BW 500, 1000, or 2000 g $fish^{-1}$) held in RAS, the skinned fillet comprises from 42.8 to 48.1% BW (Jankowska et al. 2003a, Kowalska et al. 2011, current study). Not only did the relative share of viscera impact the slaughter yield of pikeperch fillets, so did those of the head and skin, which differed fairly significantly (Table 5).

Table 5
Slaughter yield of pikeperch fed formulated feed and held in RAS (data from the literature and the current study)

	Source		
Index	Kowalska et al. (2011)	Jankowska et al. (2003a)	Current study
Body weight (g)	approx. 500 g	approx. 1000 g	approx. 2000 g
Viscera (% body weight)	4.8-5.8	16.2	10.0-11.6
Skin (% body weight)	9.8-10.2	5.5	9.7-10.3
Head (% body weight)	23.4-24.9	17.5	22.4-22.6
Skinned fillet (% body weight)	42.8-48.1	48.1	42.8-44.7

The results of the current study provide evidence that perspectives for developing pikeperch aquaculture should be linked to improving culture methods in RAS. It is essential, among other things, to develop and implement methods to protect pikeperch health including prophylactics and disease therapies, genetic and selecting programs, and also the production of single-sex populations of this species. Priority should be given to studies regarding the needs and preferences of consumers, as well as work that permits determining the impact intensive feeding has on meat quality and slaughter yield.

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