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SHORT COMMUNICATION

Effectiveness of rearing juvenile pikeperch *Sander lucioperca* (L.), fed feeds supplemented with fish oil, linseed oil, or peanut oil

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Abstract. The aim of the studies was to determine what effect feeding juvenile pikeperch (W = 59 g fish^{-1}) diets supplemented with vegetable oils had on rearing. The diets used were iso-protein (45%) and iso-energy (21 MJ kg^{-1} feed) based with a 19% fat content. The fish were reared for four weeks on commercial trout feed (group CF) or on feed supplemented with fish oil (group FO), linseed oil (group LO), or peanut oil (group PO). The highest body weight was confirmed in the fish from group LO, while the lowest was in group CF (P<0.05). Significant differences in the relative final values of the specific growth rate (SGR) were noted between groups CF and PO and LO (P<0.05). Intra-group variations in fish body weight (CV) and condition factor (CF) were similar in each of the four feeding groups (P>0.05). The best feed conversion ratio (FCR) values were noted in the groups fed feed supplemented with vegetable oils (P<0.05). The value of the protein efficiency ratio (PER) in group LO was significantly the highest (P<0.05).

Keywords: pikeperch (*Sander lucioperca*), feeding, vegetable oil, rearing indices

Two important components of commercial feeds used for intense cultivation of aquatic organisms are fish oil and fish meal. The dynamic development of aquaculture worldwide has been accompanied by increased use of these products (Vargas et al. 2008). Increasing demand for fish meal and fish oil plus limited supplies of these products has increased price and prompted the search for alternatives that are less expensive, more readily available, and safe to use. This is also why particular attention if being focused on the possibility of using alternative sources of energy, such as vegetable oils, in the manufacture of commercial fish feeds. Using these oils in fish nutrition is advantageous because they are a less expensive source of metabolic energy, they decrease demand for fish oil, protect natural resources of marine organisms, and reduce the risk of transferring or accumulating pathogens or pollution that are present in organisms caught in various basins (Piedecausa et al. 2007).

Many reports indicate that the lipid composition of feed can influence the effects of rearing fish (Kestemont et al. 2001, Zakęś et al. 2004, Schulz et al. 2005, Molnar et al. 2006). Feeding fish an improperly balanced diet can lower some rearing indices such as growth rate or the condition factor (Nyina-Wamwiza et al. 2005, Molnar et al., 2006). While some studies have shown that using vegetable oils as a source of dietary lipids can lead to lowered weight gain in fish (Gholam and Delbert 1993), other studies have indicated that using vegetable oil as a substitute for fish oil in the diets of some fish species does not lower the growth rate, the condition factor, or the effectiveness of feed conversion (Greene and Salivonchick 1990, Caballero et al. 2002). It has also been confirmed that substituting fish oil with

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Table 1

Growth, size variation, and condition of juvenile pikeperch of pikeperch fed commercial feed (CF) and feeds supplemented with fish oil (group FO), linseed oil (group LO), or peanut oil (group PO). Mean values ± SD, n = 3

Wyszczególnienie	Experimental group			
	CF	FO	LO	PO
Initial body weight (g)	$58.73^{a} \pm 0.88$	$58.98^{a} \pm 0.46$	$59.23^{a} \pm 1.35$	$59.06^{a} \pm 1.31$
Final body weight (g)	$74.43^{a} \pm 0.66$	$75.23^{ab} \pm 1.29$	$79.38^{c} \pm 1.31$	$77.78^{bc} \pm 0.47$
Daily body weight growth (g d^{-1})	$0.50^{a} \pm 0.02$	$0.54^{ab} \pm 0.05$	$0.65^{c} \pm 0.03$	$0.62^{bc} \pm 0.02$
Specific growth rate – SGR (% d^{-1})	$0.76^{a} \pm 0.05$	$0.81^{ab} \pm 0.08$	$0.94^{b} \pm 0.04$	$0.92^{b} \pm 0.01$
Initial coefficient of body weight variation – CV (%)	$30.73^{a} \pm 3.13$	$28.76^{a} \pm 1.75$	$29.25^{a} \pm 0.72$	$31.87^{a} \pm 0.72$
Final coefficient of body weight variation – CV (%)	$29.37^{a} \pm 2.41$	$29.88^{a} \pm 1.51$	$30.26^{a} \pm 0.97$	$31.90^{a} \pm 1.91$
Initial total length (cm)	$19.52^{a} \pm 0.12$	$19.57^{a} \pm 0.06$	$19.47^{a} \pm 0.11$	$19.54^{a} \pm 1.31$
Final total length (cm)	$20.51^{a} \pm 0.19$	$20.83^{a} \pm 0.45$	$20.42^{a} \pm 0.45$	$20.52^{a} \pm 0.19$
Initial condition factor – CF	$0.87^{a} \pm 0.01$	$0.83^{a} \pm 0.04$	$0.85^{a} \pm 0.01$	$0.84^{a} \pm 0.01$
Final condition factor – CF	$0.78^{a} \pm 0.01$	$0.78^{a} \pm 0.01$	$0.80^{a} \pm 0.01$	$0.79^{a} \pm 0.01$

Values in rows with the same letter index do not differ significantly statistically ($P > 0.05$)

vegetable oils has a positive influence on the survival, resistance to stress, and immunological response of the fish (Bell and Sargent 2003, Lin and Shiau 2007). To date, nutritional studies performed with cultivated fish species in which fish oil is replaced by vegetable oil have not produced only positive results. Nutritional requirements in fish are specific to both species and developmental stage (Halver and Hardy 2002), and some vegetable oils might be sources of valuable feed components.

Percid fish, including the pikeperch, *Sander lucioperca* (L.), are popular cultivated species in global aquaculture. The most widely-used feeds for rearing pikeperch are high-fat commercial feeds formulated for the nutritional needs of salmonids, and the main source of lipids is fish oil. Pikeperch can be reared in recirculating systems, where they exhibit rapid growth rates and the effective utilization of commercial feed (Zakęś et al. 2003).

The aim of the current study was to determine the influence of feeding juvenile pikeperch feeds supplemented with fish or vegetable oils (linseed or peanut) on rearing effectiveness (growth rate, condition factor, variation in fish size, effectiveness of feed utilization as expressed by the feed conversion ratio (FCR) and the protein efficiency ratio (PER)).

The study material comprised juvenile pikeperch (age 0+) of a mean initial body weight of 59 g (Table 1). The material was obtained from artificial reproduction conducted at the Dgał Experimental Hatchery of the Inland Fisheries Institute in Olsztyn (Zakęś and Szczepkowski 2004). The fish were reared in tanks with a volume of 200 dm^3 that were part of a recirculating system. The initial stocking density was 10.3-10.5 kg m^{-3}. The basic physical and chemical parameters of the water were monitored continuously during rearing. Water temperature and the contents of oxygen, ammonia nitrogen (TAN = NH_3-N + NH_4^+-N), and water pH at the rearing tank outflows were as follows: 22.0 ± 0.2°C; 5.5 ± 0.5 mg O_2 dm^{-3}; 0.36 ± 0.12 mg TAN dm^{-3}; 7.56-7.71. Water flow rates in the tanks was 4 dm^3 min^{-1}. The photoperiod was 24L:0D, and light intensity at the water surface of the tanks was 40-50 lx.

During the four-week experiment, iso-protein (45.0%) and iso-energy (21.1 MJ kg^{-1}) feed was used to compose the experimental feeds that were composed Aller Safir base feed (Aller-Aqua, Golub-Dobrzyń, Poland). It contained 45.0% protein, 3.0% fat, and 8.0% ash. The base feed was supplemented with vegetable oil or fish oil (160 g kg^{-1} feed, which was 84% of the total fat in the feed) using a vacuum pump. The fish were fed the base feed supplemented with fish oil (Möller's Tran, Oslo, Norway; group FO), linseed oil (S.P.R.P. Gal, Poznań, Poland; group LO), or peanut oil (F.LLI Ruata S.p.A., Goccia d'Oro, Italy; group PO). The fourth group of fish was fed commercial trout feed from Aller Safir (group CF), which is the same manufacturer of the feed used to make the experimental feeds (Aller-Aqua, Golub-Dobrzyń, Poland). The base for the commercial feed was the same as the base feed, but it was supplemented by the manufacturer with oils used commercially. The fat contents in all the feeds (CF, FO, LO, PO) was 19%. The feed (2 mm granulate) was delivered continuously for 19 hours per day with an automatic band feeder. The daily feed ration ranged from 1.1 to 1.2% of the biomass of the stock. All four feeding treatments (i.e., groups CF, FO, LO, PO) were conducted in three replicates (N = 3).

Body weight (W; ± 0.01 g) and total length (TL; ± 0.1 cm) were measured at the beginning and the end of the experiment. These manipulations were performed after the fish had been anesthetized with a solution of Propiscin at a concentration of 1ml dm^{-3} (Kazuń and Siwicki 2001). The stock biomass in the tanks was determined at weekly intervals during the experiment (± 1 g). The data collected was used to calculate the following rearing indices:

- daily growth rate (DGR, g d^{-1}):
  $DGR = (W_2 - W_1) \times \Delta t^{-1}$
- specific growth rate (SGR, % d^{-1}):
  $SGR = 100 \times (\ln W_2 - \ln W_1) \times \Delta t^{-1}$
- fish condition factor (CF):
  $K = (W \times 100) \times TL^{-3}$
- intra-group variation of the fish body weight coefficient (CV):
  $CV = 100 \times (SD \times W^{-1})$
- feed conversion ratio (FCR):
  $FCR = TFS \times (FB - IB)^{-1}$
- protein efficiency ratio (PER):
  $PER = (FB - IB) \times TFP^{-1}$

where:

W_1, W_2 – initial and final mean body weight (g), Δt – rearing time (days), TL – total length (cm), SD – standard deviation in body weight, FB – final biomass of the stock (g), IB – initial biomass of the stock (g), TFS – total weight of feed consumed (g), TFP – total weight of protein delivered with feed (g).

The results of all of the measurements and calculations were analyzed statistically with GraphPad Prism software (Soft. Inc., USA). The means were compared with single factor analysis of variance (ANOVA). When statistically significant differences among groups from the various experiments were confirmed ($P<0.05$), further statistical analyses were performed with Tukey's test. All values expressed as percentages were transformed with the arcsin function prior to statistical analyses.

The greatest body weight (79.38 g) was attained by the fish in group LO, while the lowest (74.43 g) was in the fish from group CF ($P < 0.05$; Table 1). The fish from group LO achieved a mean final body weight that was significantly higher than that of the fish fed feed supplemented with fish oil (group FO) ($P<0.05$). The highest daily growth rate (DGR) was noted in groups LO and PO, while the lowest was in group CF ($P<0.05$; Table 1). Significant differences in relative final values of specific growth rate (SGR) were noted between group CF and groups PO and LO ($P<0.05$; Table 1). Differences in stock biomass (kg m^{-3}) were noted in week three of rearing (Fig. 1). At the end of the experiment the stock biomass ranged from 13.02 (± 0.12) kg m^{-3} (group CF) to 13.89 kg m^{-3} (± 0.23) (group LO) ($P < 0.05$; Fig. 1). Intra-group variation of the fish body weight coefficient (CV) was similar in all four feeding treatments ($P>0.05$; Table 1). The value of the fish condition factor (CF) at the end of the experiment was also similar and ranged from 0.78 (groups CF and FO) to 0.80 (group LO) ($P>0.05$; Table 1).

The most advantageous feed conversion ratio (FCR) was noted in the groups fed diets supplemented with vegetable oil. Significant differences in the value of this coefficient were observed in the third week of rearing. The mean final values of the FCR coefficients were the lowest in groups LO and PO at 1.05 (± 0.06) and 1.10 (± 0.01) ($P<0.05$; Fig. 2). The mean final values of the PER coefficient ranged from 1.63 (± 0.08) (group CF) to 2.10 (± 0.11) (group LO), and these differences were also statistically significant ($P<0.05$; Fig. 2).

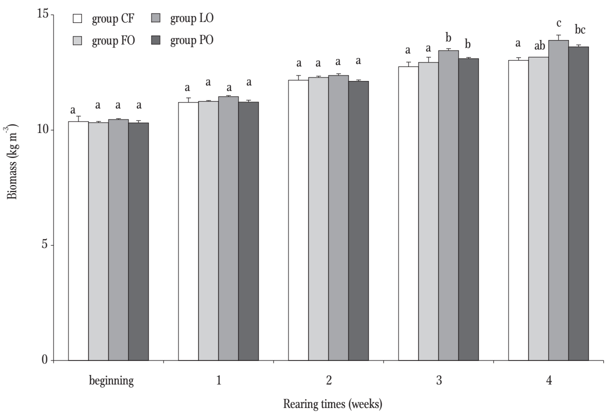

Figure 1. Biomass (mean ± SD, n = 3) of the pikeperch stock fed commercial feed (group CF) or feeds supplemented with fish oil (group FO), linseed oil (group LO), and peanut oil (group PO) in subsequent weeks of rearing. Values with the same letter index in any given week do not differ significantly statistically (P > 0.05).

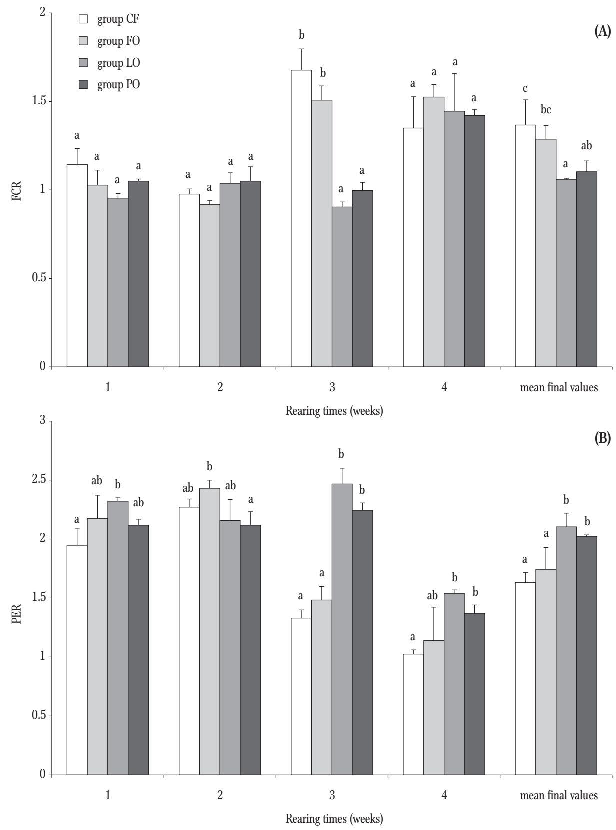

Figure 2. Feed conversion ratio (FCR) (A) and protein efficiency ratio (PER) (B) of pikeperch fed commercial feed (CF) and feeds supplemented with fish oil (group FO), linseed oil (group LO), or peanut oil (group PO) in subsequent weeks of rearing. Mean values ± SD, n = 3. Values with the same letter index in any given week do not differ significantly statistically (P > 0.05).

Using vegetable oils (either linseed or peanut) as the primary source of dietary lipids in the rearing of juvenile pikeperch did not have a negative influence on rearing. Conversely, the best growth in body weight was noted in the groups fed these oils (groups LO and PO). The mean final body weight of pikeperch fed feed supplemented with linseed oil was significantly higher than that of the fish group fed commercial feed (group CF). The study by Molnar et al. (2006) confirms that supplementation with certain vegetable oils did not have a negative influence on the effectiveness of rearing juvenile pikeperch (W = 22 and 64 g fish^{-1}). All of the basic rearing parameters of the fish fed feeds with the same quantity of fat (18%) from either fish or linseed oils were of similar values. Schulz et al. (2005) confirmed higher body weight increases in juvenile pikeperch (W = 15 g) fed feeds supplemented with linseed or soy oils, than did the fish fed feed supplemented with fish oil (the differences were not, however, statistically significant). In turn, Ng et al. (2003) observed that rates of body weight increase of African catfish, *Clarias gariepinus* (Burchell), fed feed supplemented with palm oil was significantly faster than individuals fed feed supplemented only with fish oil. In European sea bass, *Dicentrarchus labrax* (L.) (W = 90 g fish^{-1}) or rainbow trout, *Oncorhynchus mykiss* (Walbaum) (W = 240 - 780 g fish^{-1}), growth rates were similar regardless of the type of oil used in the feed (rapeseed, linseed, olive oils) (Caballero et al. 2002, Mourente et al. 2005). The partial replacement of fish oil with vegetable oil did not lower the growth rates of cultivated fish (Dosanjh et al. 1984, Thomassen and Rosjo 1989, Greene and Salivonchick 1990). However, using vegetable oil as the only lipid source in fish feeds might have a negative impact on their growth rates. One example might be the rearing of juvenile sunshine bass (a white bass, *Morone chrysops* (Rafinesque), × striped bass, *M. saxatilis* (Walbaum) hybrid) which was unsuccessful when dietary fat was from one oil only (Gholam and Delbert 1993). Among fish from five dietary groups (feed supplemented with one oil: fish, coconut, saffron, linseed, or olive), those fed fish oil had the fastest growth rates. The worst of the fish oil substitutes was corn oil since the fish fed this supplement exhibited the lowest growth rates. It should be emphasized that in some of the experiments mentioned above such as Mourente et al. (2005) and Schulz et al. (2005), in which no significant differences were noted among the basic rearing parameters of fish reared on feed with lipid compositions of varied quality, the source of fat was not exclusively vegetable oil, but also fish oil. The base used to compose the experimental feeds for the current experiment also contained 3% fat that was derived primarily from fish meal. It cannot be ruled out that this lipid source could have played a role in healthy, rapid fish growth.

Nutritional studies have indicated that fish can use dietary lipids, protein, and carbohydrates as sources of energy. In the case of predatory fish, the preferred sources of energy are lipids and protein (Halver and Hardy 2002). The optimal share of protein, lipids, and carbohydrates in the fish diet depends both on the species and the ontogenetic developmental stage (Murai 1992). Nyina-Wamwiza et al. (2005) conducted studies on pikeperch (W = 50 g), in which the greatest increases in body weight were confirmed in fish fed feeds with protein/fat/carbohydrate shares of 43/10/15, 43/22/20, and 50/16/20. These researchers learned that the impact of protein is more significant for the effectiveness of rearing (including growth) than are lipids or carbohydrates. Similar results were obtained by Barrows et al. (1988) with walleye, *Sander vitreus* (Mitchill), and by Fiogbe et al. (1996) and Kestemont et al. (2001) for European perch, *Perca fluviatilis* L. The experimental feed used in the current experiment had a protein content of 45%, carbohydrates – 16%, and fat – 19%, which, according to the studies cited above, meets the basic nutritional needs of the species studied. It can be assumed that the feeds tested in the current study, including those supplemented with vegetable oils, ensured the rapid growth of the fish.

The fish feeds containing linseed and peanut oils had similar, significantly lower FCR coefficients than did commercial feed and that supplemented only with fish oil. Additionally, the value of the PER coefficient in group LO was significantly the highest. In turn, Molnar et al. (2006) confirmed that feeding pikeperch feed supplemented with vegetable oils, including linseed oil, had no impact on the differences in the values of the FCR coefficient. In studies of rainbow trout (W = 50 g), in which fish oil was substituted with soy oil (at a rage of 0 to 50%), the FCR coefficient in all groups was also similar (Figueiredo-Silva et al. 2005). It should be emphasized that the study period during which pikeperch were fed the base feed enriched with linseed, peanut, or fish oils following which the rearing parameters were analyzed was relatively short (four weeks), and differences in the FCR coefficient could have been a reaction of the fish to the new nutrients in their diets. It cannot be ruled out, however, that in the long term, these inter-group differences might not be sustained. Low values of the FCR coefficient might also be linked to the base feed used to compose the experimental diets. Zakęś et al. (2004) noted high FCR coefficient values (ranging from 2.9 to 4.7) when pikeperch were fed fully experimental feeds that were composed without the use of a base feed and in which the fat source was rapeseed oil. In light of this, it could be assumed that peanut and linseed oils are better substitutes for fish oil than is rapeseed oil.

The rapid growth rates of the fish and the low values of the FCR coefficients might be evidence that feed containing vegetable oils is assimilated well. It might also indicate that the feeds tested in the current study met the nutritional needs of juvenile pikeperch. This is indicated by the high values of the PER coefficient in groups LO and PO. Performing tests of the biological quality of the material (including histological, hematological, and proximal composition of the bodies) would doubtless provide a fuller picture of the impact substituting vegetable oils for fish oil has on this species. Any application of vegetable oils during a certain period of pikeperch rearing has a positive impact on the basic rearing parameters, and it cannot be ruled out that the long-term effects might determine the biological quality of the material. It is recommended, thus, to perform studies of a wider scope aimed at determining the impact feeding this type of diet has on pikeperch, as well as what effect the level of supplementation with fish oils has on the overall effectiveness of the rearing of this species.

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Streszczenie

Efektywność podchowu juwenalnego sandacza *Sander lucioperca* (L.) żywionego paszami z dodatkiem tranu, oleju lnianego lub arachidowego

Celem badań było określenie wpływu żywienia juwenalnego sandacza (W = 59 g ryba^{-1}) paszami suplementowanymi olejami roślinnymi na efekty jego podchowu. W żywieniu zastosowano pasze izoproteinowe (45%), izoenergetyczne (21 MJ kg^{-1} paszy) o 19% zawartości tłuszczu. Ryby podchowywano przez 4 tygodnie i żywiono komercyjną paszą pstrągową (grupa CF) lub paszami suplementowanymi tranem (grupa FO), olejem lnianym (grupa LO) lub olejem arachidowym (grupa PO). Największą masę ciała stwierdzono u ryb z grupy LO, zaś najniższą w grupie CF (P < 0,05). Istotne różnice w wartościach względnego końcowego przyrostu masy ciała (SGR) odnotowano między grupami CF, a PO i LO (P < 0,05). Zróżnicowanie wewnątrzgrupowe masy ciała (CV) i współczynnik kondycji (K) ryb osiągnęły zbliżoną wartość w czterech grupach żywieniowych (P > 0,05). Współczynnik pokarmowy pasz (FCR) najkorzystniejszą wartość przyjął w grupach żywionych paszami z dodatkiem olejów roślinnych (P < 0,05). Wartość współczynnika wydajności wzrostowej białka (PER) w grupie LO była istotnie najwyższa (P < 0,05).