Aquacult Int (2006) 14:577–586
DOI 10.1007/s10499-006-9056-z

ORIGINAL PAPER

Growth performance and body composition of pike perch (*Sander lucioperca*) fed varying formulated and natural diets

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Received: 21 July 2005 / Accepted: 17 May 2006 /
Published online: 14 July 2006

Abstract To assess the effect of dietary composition on growth performance and body composition of pike perch (*Sander lucioperca*), fingerlings with an initial body weight of 1.36 g (just trained to accept formulated feed) were fed three experimental diets in triplicate for 90 days. Two feeding groups were fed with formulated diets (CD, CD+7) containing varying levels of crude lipid (CL) of 14.65% and 21.94% dry matter (d.m.) with crude protein (CP) levels of 59.73% and 56.56%, and one feeding group was fed a natural diet (chironomids, CP = 65.93% d.m.; CL = 7.20% d.m.). Furthermore, pike perch of the same age caught in different natural habitats were analysed to determine their naturally fluctuations in body composition. Specific growth rate (SGR; CD = 3.36, CD+7 = 3.47) and feed conversion ratio (FCR; CD = 1.02, CD+7 = 0.93) of fish fed formulated diets did not differ significantly with rising dietary lipid content, due to high variability within the individuals of each feeding groups. In contrast, pike perch fed with chironomids showed a significantly lower SGR of 2.49 and higher FCR of 2.37 (on a dry matter basis). Body composition of pike perch fed formulated diets was affected by dietary composition and showed increased lipid contents [CD=6.25% original matter (o.m.), CD+7 = 9.00% o.m.] with rising dietary lipid levels. Pike perch of CD and CD+7 feeding groups showed significant increased hepatosomatic indices (HSIs) of 1.99 and 2.05 in contrast to fish fed chironomids with HSI of 1.11. Fish caught in the different natural habitats were characterised by low body lipid and dry matter contents of 0.64–1.88% o.m. and 21.08–23.75% o.m. Higher lipid incorporation of fish fed with formulated diets accompanied with poor benefit on growth performance at higher dietary lipid content indicated that pike perch ability to utilise lipids is low when dietary crude protein content is higher than 56.56%.

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Keywords Pike perch · Growth performance · Feed efficiency · Lipid metabolism · Body composition

Abbreviations

CD	Commercial diet
cf	Condition factor
CL	Crude lipid
CP	Crude protein
d.m.	Dry matter
FCR	Feed conversion ratio
HSI	Hepatosomatic index
L_f	Final body length
o.m.	Original matter
PER	Protein efficiency ratio
P/E	Protein/energy ratio
SGR	Specific growth rate
SR	Survival rate
T	Duration of the experiment
W_i	Initial body weight
W_f	Final body weight
WG	Weight gain
W_l	Liver weight
$Wprot_f$	Weight of dietary crude protein supply
W_{TFS}	Weight of total feed supplied

Introduction

In recent years species of the family Percidae, such as North American walleye (*Sander vitreum*), yellow perch (*Perca flavescens*), Eurasian perch (*Perca fluviatilis*) and pike perch (*Sander lucioperca*) have been identified to diverse inland aquaculture. Former studies have shown that pike perch fingerlings of 0.5–1.0 g can be trained to accept formulated feed by gradual substitution of natural food sources (e.g. chironomids) with artificial diets over a period of 2–4 weeks (Zakes 1997; Kamstra et al. 2001; Zienert and Wedekind 2001; Baer et al. 2001; Ljunggren et al. 2003; Schulz et al. 2005). There are no specific feed formulations for pike perch yet, that pike perch are commonly fed, high energy diets primarily developed for salmonids.

Lipids are important dietary components in the nutrition of fish. They supply energy and are components of membranes, pheromones, hormones, vitamins or pigments (Sargent et al. 1989). Lipids can also spare dietary protein from metabolisation in energy demanding processes and thus limit ammonia excretion in fish (Watanabe et al. 1987; Rennert 1994; Steffens 1996). On the other hand, excessive dietary lipid supply can lead to decreased feed consumption and reduce the dietary nutrient utilisation accompanied by decreased growth performance (Watanabe 1982; Ellis and Reigh 1991; Nematipour et al. 1992). Moreover, the amount of dietary lipid can also affect the body composition of fish (Watanabe et al. 1987; Shearer 1994; Steffens 1996). It has been shown that high energy diets may increase peritoneal fat deposition and flesh lipid content and, thus, affect flesh quality and filleting yield (Einen and Roem 1997; Company et al. 1999).

Studies carried out on juvenile Eurasian perch (2.9 g initial body weight) or yellow perch (51 g initial body weight) indicate that low dietary fat (10%) and high protein content (>40%) seem to be beneficial for growth performance of percids (Fiogbé et al. 1996; Brown et al. 1996; Kestemont et al. 2001; Xu and Kestemont 2002). Furthermore, increasing lipid tissue incorporation and peritoneal deposition observed in percids indicate low utilisation of dietary lipid supply. Similar results of limited dietary lipid utilisation have been reported for common dentex (*Dentex dentex*), sea bream (*Sparus aurata*) and European sea bass (*Dicentrachus labrax*) or Murray cod (*Maccullochella peelii peelii*) (Company et al. 1999; De Silva et al. 2002).

Wild pike perch are characterised by low body and tissue lipid contents, and development of feed formulations for pike perch reared in aquaculture facilities should carefully evaluate the increasing dietary lipid levels. Therefore, the aim of this study was to determine the effect of varying dietary lipid level on growth performance, body composition and survival of juvenile pike perch in contrast to those that were fed a natural food source (chironomids). Furthermore, pike perch of the same age caught in different natural habitats were analysed to determine natural fluctuations in body composition as a reference.

Material and methods

Culture system

The trial was conducted in the experimental facilities of the Leibniz Institute for Freshwater Ecology and Inland Fisheries (Berlin, Germany) for a period of 90 days. The test fish were reared in a recirculation system consisting of nine square tanks with a volume of 500 l and a water flow of 2.5 l/min each. The recirculation system was equipped with a lamellar filter for mechanical water purification and a trickling filter for biological water purification. The daily water exchange amounted to 10% of the total unit volume (9 m^3). Water temperature, pH, O_2 and conductivity were measured daily (WTW multi 340 I, Weilheim, Germany) and totalled, on average, 23.2°C (±1.1°C), 7.5 (±0.2), 6.7 mg/l (±0.6 mg/l) and 780 μsm/cm (±17 μsm/cm), respectively.

Experimental diets

Three experimental diets were used in this study. One experimental feeding group was fed with a commercial diet (CD; Trouvit, Pro aqua). The second experimental feeding group was fed with the same commercial diet with 7% fish oil added (CD+7), by manualspraying. The last experimental group was used as a reference group and was fed with frozen chiromonids (*Chironomus* ssp.) as a natural feeding source. The nutrient composition of the experimental diets is shown in Table 1. Formulated diets CD and CD+7 differed in crude protein content (CP) with 59.73% and 56.56%, respectively, on a dry matter (d.m.) basis and in crude lipid (CL) content with 14.65% and 21.94%, respectively. Resulting gross energy (GE) and protein-to-energy ratio (P/E ratio) calculations resulted in 22.51 MJ/kg d.m. and 26.53 g CP/MJ GE for diet CD and 24.04 MJ/kg d.m. and 23.53 g CP/MJ GE for diet CD+7. Chironomids were characterised by high crude protein and low crude lipid

Table 1 Nutritional composition of experimental diets (*NFE* nitrogen-free extracts including crude fibre)

Component	CD	CD+7	Chironomids
Dry matter (%)	94.73	96.66	10.24
Crude protein, CP (% d.m.)	59.73	56.56	65.93
Crude lipid, CL (% d.m.)	14.65	21.94	7.20
Crude ash, CA (% d.m.)	11.95	11.33	10.59
NFE[a] (% d.m.)	13.68	10.17	16.27
Gross energy, GE[b] (MJ/kg d.m.)	22.51	24.04	21.49
P/E ratio[c] (g CP/MJ GE)	26.53	23.53	30.68

[a]NFE = 100 – (CP + CL + CA)

[b]Calculated from Crude protein = 23.9 kJ g^{-1}, crude lipids = 39.8 kJ g^{-1}, NFE = 17.6 kJ g^{-1}

[c]Protein/energy ratio: g protein/MJ gross energy

contents of 65.93% and 7.20%. Chironomids contained a lower GE of 21.49 MJ/kg d.m than formulated diets and a high P/E ratio of 30.68 g CP/MJ GE. Pellet size of diets CD and CD+7 ranged between 0.7 mm. and 1.5 mm.

Experimental fish

Pike perch fry used in this experiment were obtained from a commercial fish farm (Viskweekcentrum Valkenswaard, Leende, Netherland). They were fed during the first 50 days with sieved zooplankton corresponding to their body size and, in the last days, with larvae of *Chironomus* ssp. After these 50 days, the fish were trained to accept formulated feed within 2 weeks as described by Zienert and Wedekind (2001).

For the determination of the natural fluctuation in pike perch body composition, condition factor (*cf*) and hepatosomatic index (HSI), individuals of the same age were caught in different habitats in October and November by gill nets. Ten fish each were obtained from two eutrophic lakes (Lake Müggelsee and Lake Langer See), from the river Oder and from ponds of a commercial fish farm located in Lausitz, Brandenburg State, Germany.

Experimental design

A total of 225 pike perch juveniles of 1.36 g initial body weight were randomly distributed in nine tanks in the recirculation system, and each tank was stocked with 25 fish. The three experimental diets were randomly allotted in triplicate. In order to reduce the affects of territorial behaviour on feed intake, we chose a high, pre-determined, feeding rate, which provided feed in excess to satiate each individual. The experimental groups were weighed every 2 weeks so that the daily feed supply could be adjusted, on average, to 5% of total fish biomass (based on dry matter content of different diets). Fish were fed manually, and the amount was supplied in three rations per day.

Calculations

At the end of the experiment the growth performance was assessed by determination of weight gain (WG), specific growth rate (SGR), feed conversion ratio (FCR), protein efficiency ratio (PER), *cf* and HSI as follows:

Weight gain (g) = $W_f - W_i$
Feed conversion ratio = $W_{TFS}/(W_f - W_i)$
Specific growth rate (%/day) = 100 ($\ln W_f - \ln W_i$)/T
Protein efficiency ratio = $(W_f - W_i)/Wprot_f$
condition factor (*cf*) = $W_f/L_f^3 \times 100$
Hepatosomatic index = $W_l / W_f \times 100$

where W_i and W_f are the initial body weight and final body weight (in grammes), W_{TFS} is the weight of total feed supplied (in grammes), T is the duration of the experiment (in days), $Wprot_f$ is the weight of dietary crude protein supply, L_f is the final body length and W_l is the liver weight.

Furthermore, survival rate (SR), expressed as percentage of fish surviving out of total fish, was determined at the end of the experiment.

Chemical analyses of body composition

All fish (maximum 25) from each tank at the end of the feeding trial were killed for nutrient analyses of the whole fish. For calculation of the HSI, the weight of liver was determined. Afterwards, all fish from each tank (+liver) were homogenised separately (n = 3, for each experimental treatment) and stored at below –20°C in a freezer prior to undergoing chemical analysis (in duplicate) of whole fish. Fish obtained from the different natural habitats (ten individuals each) were also homogenised and stored at below –20°C in a freezer prior to undergoing chemical analyses.

Dry matter was determined by freeze drying to a constant weight. Subsequently, crude ash, protein and lipid content were determined in the samples. Crude ash was analysed by being burned in a muffle furnace at 750°C for 4 h. Crude protein (N × 6.25) was determined by the Kjeldahl distillation method (Kjeltec system, Tecator). Crude fat was analysed by petroleum ether extraction in a Soxhlet apparatus (Soxtec system, HT Tecator).

Statistical analyses

The influence of dietary nutrient composition on growth response and body composition of different feeding groups (in triplicate, n = 3) was tested by one way analysis of variance (ANOVA). Differences in means were evaluated for significance by the multiple range tests of Tukey HSD ($P \leq 0.05$) for homogeneous variances (Levene test) and by Dunnett T3 ($P \leq 0.05$) for inhomogeneous variances, respectively. The data are presented as means ± standard deviation of triplicate groups. Calculations were performed with the SPSS software package (SPSS 2003).

Results

Growth performance

The growth response of fish fed with different experimental diets over a period of 90 days is shown in Table 2. Mean final body weight, SGR and FCR of pike perch were significantly affected by the dietary source. Pike perch fed with chironomids showed the lowest final body weight (12.77 g) and SGR (2.49%/day). Fish fed with

Table 2 Mean individual weights, lengths, growth parameters, HSIs and *cfs* of fish fed varying diets. *Within each line* the values with the same superscript letter do not differ significantly ($P < 0.05$), ± standard deviation

Parameter	CD	CD+7	Chironomids
Initial body weight, W_i (g)[1]	1.36 ± 0.59	1.36 ± 0.59	1.36 ± 0.59
Final body weight, W_f (g)	28.12[a] ± 9.28	30.91[a] ± 13.96	12.77[b] ± 2.91
Initial body length, L_i (cm)[1]	5.50 ± 0.85	5.50 ± 0.85	5.50 ± 0.85
Final body length, L_f (cm)	15.78[a] ± 1.54	16.10[a] ± 1.95	11.91[b] ± 0.99
Weight gain (g)	26.76[a] ± 7.92	29.55[a] ± 12.60	11.41[b] ± 3.37
SGR (%/day)	3.36[a] ± 0.15	3.47[a] ± 0.18	2.49[b] ± 0.05
FCR[2]	1.02[a] ± 0.14	0.93[a] ± 0.16	2.37[a] ± 0.11
Survival (%)	98.67[a] ± 1.33	96.00[a] ± 2.67	98.67[a] ± 1.33
HSI	1.99[a] ± 0.36	2.05[a] ± 0.25	1.11[b] ± 0.35
cf	0.69[a] ± 0.03	0.70[a] ± 0.13	0.75[b] ± 0.01
PER	1.66[a] ± 0.23	1.94[a] ± 0.34	0.64[b] ± 0.03

[1]Based on a subsample of 30 individuals

[2]FCR calculations for chironomid-fed fish are based on dry matter

diets CD and CD+7 showed significantly higher final body weights of 28.12 g and 30.91 g and SGR (3.36%/day and 3.47%/day). Growth performance of the experimental groups fed with formulated diets CD (WG 26.76 g; FCR 1.02) and CD+7 (WG 29.55 g; FCR 0.93) did not show significant differences, due to high internal variability within the groups. Feed conversion based on the dry matter intake of pike perch fed with chironomids was at the highest level (FCR 2.37). PER increased with rising dietary lipid content of formulated diets and amounted to 1.66 and 1.94 for experimental groups CD and CD+7. In contrast, fish fed chironomids showed the lowest dietary protein conversion (PER 0.64).

The health status, expressed as HSI and *cf*, was significantly affected by the dietary source. Pike perch fed the formulated diets CD and CD+7 showed increased HSIs of 1.99 and 2.05 and decreased *cfs* of 0.69 and 0.70, in contrast to 1.11 (HSI) and 0.75 (*cf*) of fish fed chironomids. Survival of fish was above 96% at the end of the feeding trial in all groups and was not affected by the dietary sources.

Body composition of experimental fish

The body composition analysed at the end of the experiment is described in Table 3 as percentage of original matter (o.m.). In general, it was obvious that dry matter and crude lipid content of the analysed fish was positively correlated with increasing

Table 3 Means and standard deviations of final composition of pike perch (whole fish) fed varying experimental diets; values are expressed as percentage of original matter (% o.m.). *Within each line* the values with same superscript letter do not differ significantly ($P < 0.05$)

Final composition[1]	CD	CD+7	Chironomids
Dry matter (% o.m.)	28.57[a] ± 0.56	30.12[b] ± 0.65	26.97[c] ± 0.32
Crude protein (% o.m.)	18.18[a] ± 2.78	17.36[a] ± 1.01	18.08[a] ± 1.23
Crude lipid (% o.m.)	6.25[a] ± 0.58	9.00[b] ± 0.42	4.05[c] ± 0.55
Crude ash (% o.m.)	3.74[a] ± 0.04	3.57[a] ± 0.10	3.76[a] ± 0.15

[1]Values are means obtained from triplicate analyses for each experimental group ($n = 3$) from a sample of all homogenised fish per tank and analyses

dietary lipid level and negatively correlated with increasing protein level. Thus, fish fed diets CD and CD+7 differed significantly in body lipid (6.25% and 9.00%) and dry matter content (28.57% and 30.12%). Body analyses of fish fed chironomids yielded the lowest crude lipid and dry matter content, of 4.05% and 26.67%. Crude protein and ash content of experimental groups ranged between 17.36–18.18% o.m. and 3.57–3.76% o.m. without any significant effect of dietary source.

Body composition, HSI and *cf* of fish caught in different natural habitats

In general, the body composition of pike perch caught in different natural aquatic environments showed only slight differences between each other (Table 4). In contrast to fish fed with experimental diets, the dry matter and lipid contents of pike perch caught in their natural habitat were drastically decreased and ranged between 21.08–23.75% and 0.64–1.88 % o.m., respectively. Crude protein (16.01–18.25% o.m.) and crude ash (3.24–4.07% o.m.) were on equal levels compared with pike perch fed with experimental diets. The HSI (1.04–1.17) of pike perch from different natural habitats were on the same levels as those calculated for fish fed with chironomids in the feeding trial. The *cf* of 0.64–0.76 fluctuated according to the *cf* of fish fed with different experimental diets.

Discussion

Growth performance

Pike perch growth performance, with SGRs ranging from 2.49%/day to 3.47%/day, observed in this investigation was on a comparable high level to those found in other studies of pike perch of the same body size. Schulz et al. (submitted) obtained SGRs of 2.44–3.11%/day when pike perch of 1.01–1.09 g were fed with varying dietary protein contents. Zakes and Demska-Zakes (1996) found SGRs of 2.09%/day and 3.01%/day for juvenile pike perch with initial body weights of 0.32 g fed with zooplankton and commercial diets.

This study underlines the notion that formulated diets are beneficial for growth performance (SGR, CD 3.36 and CD+7 3.47) when compared with natural diet sources (SGR, chironomids 2.49). Furthermore, low feed conversion ratios of 1.02 (CD) and 0.93 (CD+7) show efficient utilisation of formulated diets, as could be

Table 4 Body composition, HSI and *cf* of pike perch caught in different natural habitats. Body composition (whole fish) values are expressed as percentage of original matter (% o.m.)

Parameter[a]	River Oder	Lake Müggelsee	Lake Langer See	Pond at Lausitz
Mean weight (g)	7.2	6.9	7.4	8.1
Dry matter (% o.m.)	21.08	23.40	21.56	23.75
Crude protein (% o.m.)	16.30	18.25	17.20	16.01
Crude lipid (% o.m.)	0.64	1.72	1.01	1.88
Crude ash (% o.m.)	4.07	3.24	3.58	3.92
HSI	1.04	1.07	1.17	1.17
cf	0.67	0.66	0.64	0.76

[a]Values are means obtained from duplicate analyses from a sample of ten homogenised fish per habitat

demonstrated in the study by Nyina-Wamwiza et al. (2005) with FCR of 0.97–1.78 (calculated from presented feed efficiency). Owing to the high variability in individual growth performance in each feeding group, no significant differences could be found with increasing dietary lipid levels.

Utilisation of dietary protein for fish growth is linked with the amount of dietary protein and the availability of non-protein energy sources. Increasing inclusion of metabolisable non-protein energy, mainly lipids, has been found to spare dietary protein from energy metabolism and to increase its utilisation for fish growth. Nyina-Wamiza et al. (2005) did not observe a significant protein sparing effect in the nutrition of pike perch at higher dietary lipid inclusion levels, as is known from other carnivorous fish species such as salmonids (Takeuchi et al. 1978). Although Xu et al. (2001) reported a significant increase in WG, SGR and FCR with rising dietary lipid contents from 11.7% to 19.3% (and decreasing crude protein levels from 46.1% to 41.6%) for near-related Eurasian perch (*Perca fluviatilis*), Mathis et al. (2003) reported the highest SGR at dietary lipid contents of 16.3% (CP 46.6%), compared with 11.9% (CP 49.2%) and 22.2% (CP 43.2%). Mathis et al. (2003) concluded that the Eurasian perch's ability to spare dietary protein by lipids is low. These results are in accordance with limited dietary lipid utilisation observed in common dentex (*Dentex dentex*), sea bream (*Sparus aurata*) and European sea bass (*Dicentrachus labrax*, Dias et al. 1998; Company et al. 1999) or Murray cod (*Maccullochella peelii peelii*, (De Silva et al. 2002). Moreover, Nematipour et al. (1992) found a negative impact of increasing dietary lipid content greater than 8% in hybrid striped bass.

It is well known that fish metabolise excessive dietary protein preferentially to lipid or carbohydrate as energy source. Therefore, dietary protein contents lower than those used in this study should be more adequate to assess the effect of increasing dietary lipid levels on potential protein sparing effect in the nutrition of pike perch. Nevertheless, the P/E ratio of formulated diets of 26.53 CP/MJ GE and 23.54 CP/MJ GE are in the range of the P/E ratio (25.92 g CP/MJ GE) recommended as the most efficient diet in the experiments of Nyina-Wamwiza et al. (2005). Lower optimum dietary P/E ratios reported for other percids (Eurasian perch 18.4–22.0 g CP/MJ GE, Fiogbé et al. 1996; Mathis et al. 2003; yellow perch 20–22 g CP/MJ ME, Ramseyer and Garling 1998) indicate that pike perch could have the ability for increased dietary protein utilisation. In comparison with reports for other percids, feed conversion obtained in the presented study was excellent. The resulting PER increased from 1.66 to 1.94 with rising dietary lipid level from 14.65% d.m. to 21.94% d.m. (Owing to high variability within the feeding groups, no statistical differences were calculated.) This underlines the suggestion that pike perch are potentially able to utilise dietary lipids instead of proteins for energy metabolism and should be focussed on in further studies.

Body composition

The presented results of the body composition analyses showed that dietary lipid content affects the body composition of pike perch markedly. Feeding diets with increasing lipid content resulted in significantly higher lipid accumulation and higher dry matter content of whole fish, as it was demonstrated for different other fish species such as sunshine bass (Nematipour et al. 1992), bagrid catfish (Ng et al. 2001) or Eurasian perch (Xu et al. 2001; Mathis et al. 2003). In contrast to the fish fed formulated diets, those fed chironomids displayed the lowest lipid levels of whole-body composition. This indicates that formulated diets with higher amounts of non-protein energy could lead to significant body lipid incorporation. In contrast, wild pike perch were characterised by low lipid contents, ranging from 0.64% o.m. to 1.88% o.m. The lipid content of wild fish fluctuates within the year and reaches the highest amounts in autumn, when the fish used in the presented analyses were caught. According to the results of Bergström (1989), carried out with salmonids, pike perch reared in aquacultural facilities show higher lipid incorporation than do wild fish. This could be caused by rearing management or the dietary composition or dietary energy supply. Low HSIs, ranging from 1.04 to 1.17, in wild pike perch were comparable to those in fish fed on chironomids and reared under intensive conditions (1.11). Furthermore, pike perch fed on formulated diets showed increased HSIs (1.99 and 2.05), which indicate that high amounts of non-protein energy in the diet influence liver status and body composition. This relationship between dietary lipid content and body fat accumulation, especially in the liver, is a major concern in the nutrition of percids and some other cool-water species such as sunshine bass (Nematipour et al. 1992), hybrid striped bass (Brown et al. 1992), yellow perch (Brown et al. 1996) and gilthead sea bream (Ibeas et al. 1994). Pike perch fingerlings fed with formulated diets seem to utilise protein most efficiently, and excess dietary protein is catabolised preferentially over lipids and carbohydrates for energy metabolism, as is described by Wilson (1989).

In conclusion, we can state that pike perch juveniles fed formulated diets show better growth response than those fed a natural diet. Furthermore, results indicate low ability to utilise dietary lipids for energy metabolism in order to spare dietary protein. In further investigations dietary lipid utilisation of pike perch should be focussed on in order to reduce high body lipid incorporation and potentially decreasing product quality.

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