The effects of diet and feeding techniques on growth factors and meat quality of common carp (*Cyprinus carpio*)

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Abstract

The study was conducted for 134 days. Common carp fry (60g ± 0.3g) were fed using two different diets containing only plant protein sources, without any animal protein inclusions. Diets were administered by two different methods: an automatic band feeder (diet 28/7 F and 28/15 F) for 12 hours a day (9.00 a.m. – 9.00 p.m.) and by hand (diet 28/7 H and 28/15 H) once a day (at 9 am). Weight, Specific Growth Rate (SGR), Protein Efficiency Ratio (PER), Fat Retention Index (FR) and Protein Retention Index (PR) were statistically higher in fish fed with the automatic feeder. On the contrary, the value of FCR was statistically higher in fish fed by hand. Diet composition did not have significant influence on growth performance. Survival rate was not statistically different among groups (85-96%). There was no significant effect of feeding method or diet on meat quality, such as color and fat content.

Keywords: Automatic feeders, Common carp, Feeding by hand, Feeding techniques, Plant protein sources

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Introduction

One of the crucial components of fish feed is fish meal, since it is a good source of nutrients – such as amino acids, fatty acids, vitamins, and minerals which improve growth performance and meat quality (Gaylord *et al*., 2010; Gui *et al*., 2010; Kumar *et al*., 2010). Due to the high costs of fish meal and the dramatic decrease of fish catch used as fish meal, the demand for alternative protein sources is increasing (Hardy, 2008; Kraugerud and Svihus, 2011). One of the most used plant feed is soybean meal (SBM), due to its high protein level and balanced amino acid profile (Gatlin *et al*., 2007; Papan and Moghaddam, 2008;Collins *et al*., 2012). Other sources of proteins are by-products from the oil industry, such as oilcake or extracted meals from rape, sunflower, peanut or cotton (Higgs *et al*., 1988; Yue and Zhou, 2009; Nogales *et al*., 2011). However, the most important disadvantage of plant feedstuff components is the presence of antinutritional factors (Francis *et al*., 2001), which may negatively affect fish growth performance.

The aim of the study was to determine the influence of two different feeding methods (automatic band feeding and hand feeding) and two different diets containing only plant protein sources, with no animal protein inclusions, on growth performance and meat quality of common carp.

Materials and methods

Diets

During the growth trial, fish were given two commercial diets: PANTO Karpfengold K 28/7 and PANTO Karpfengold K 28/15, produced by HL Hamburger Leistungsfutter GmbH Hamburg, Germany. Diet nomenclature, percentage of nutrients, and feeding techniques are reported in Table 1.

Detailed characteristics of diets, based on the producer's data, are reported in Table 2. Both diets contained the following components: soybean meal toasted, toasted and dehulled soyabean, wheat, triticale, rapeseed meal, soyabean oil, aminoacids, mineral components, vitamin B, vitamin C stabilized, trace elements and antioxidants.

Growth trial

Common carp fry of 60 ± 0.3g mean initial body weight were obtained from a commercial farm dealer. During the acclimatization period (about 3 weeks), fish were fed on a commercial diet (Aller Classic, Aller-Aqua Polska Ltd, Nożynko, Poland) containing 300 g · kg^{-1}crude protein and 18,4 MJ · kg^{-1} gross energy (GE).

The growth trial was conducted in the Experimental Station of Feed Production Technology and Aquaculture in Muchocin of the Poznań University of Life Sciences. The growth trial was carried out for 134 days (from May 17 to September 28, 2012).

Table 1: Variants of feeds.

Variant of feed	Protein content [%]	Fat content [%]	Feeding technique
Experiment code: PANTO Karpfengold K 28/7			
28/7 F	28 %	7 %	automatic feeders
28/7 H	28 %	7 %	feeding by hand
Experiment code: PANTO Karpfengold K 28/15			
28/15 F	28 %	15 %	automatic feeders
28/15 H	28 %	15 %	feeding by hand

Table 2: Feed characteristics.

Nutrient per kg	Feed	
	PANTO Karpfengold K 28/7	PANTO Karpfengold K 28/15
Protein (%)	28.0	28.0
Fat (%)	7.0	15.0
NFE (%)	39.0	32.0
Ash (%)	9.0	9.0
Fibre (%)	4.0	4.0
Lysine (%)	1.6	1.7
Calcium (%)	1.3	1.3
Magnesium (%)	0.3	0.3
Sodium (%)	0.5	0.4
Phosphorus (%)	1.0	0.9
Iodine (mg)	1.0	1.0
Copper (mg)	24.0	24.0
Manganese (mg)	45.0	45.0
Selenium (mg)	0.3	0.3
Zinc (mg)	100.0	100.0
Iron (mg)	115.0	110.0
Vitamin A (IE)	12000	12000
Vitamin D_3 (IE)	1450	1450
Vitamin E (mg)	100	100
Energy brutto (MJ kg^{-1})	17.1	18.9
E/P (kJ g^{-1} total protein)	61.07	67.39

The experimental groups were as follows: group 1 fed PANTO K 28/7 diet by an automated feeder; group 2 fed PANTO K 28/7 diet by hand; group 3 fed PANTO K 28/15 diet by an automated feeder; group 4 fed PANTO K 28/15 diet by hand. Each group was constituted by 90 individuals distributed in three ponds with a density of 30 fish/pond. Ponds (with a surface area of 40 m² each) were individually supplied with water in an open system. Ponds were designed in such a way that the maximum water level with constant water flow was maintained for the whole duration of the trial. During the trial the water temperature (°C) and the dissolved oxygen content (mg O_2/dm^3) were measured daily (at 9 a.m.) using a microcomputer oxymeter (ELMETRON CO 315, Elsent Wrocław, Poland) The water pH was measured once a week with a WTW pH meter (WTW Multi Line P3, WTW Weilheim, Germany).

During the growth trial fish were fed six days a week, from Monday to Saturday. Diets 28/7 F and 28/15 F were provided by automatic band feeders for 12 hours (9 a.m. – 9 p.m.). Diets 28/7 H and 28/15 H were administered by hand once a day at 9 am. The calculation of the daily diet ration was based on the carp feeding key developed by Miyatake (1997), taking into consideration the water temperature and the current fish weight. The diet ration and the rearing indices were quantified every ten days, in conjunction with the fish weight measurements.

Fish body composition, slaughter traits and meat composition

Prior to the commencement of the growth trial and immediately after it fish samples (three fishes for each group) were taken to determine their proximal body composition. Fish were anesthetized with a solution of the Propiscin anesthetic (Siwicki, 1984) decapitated, ground (KNIFETEC 1095 Sample Mill, FOSS TECATOR, Höganäs, Sweden) and homogenized (Laboratory homogenizer H500, POLEKOLAB, Warsaw, Poland). Dry matter, crude protein, crude lipid and ash were measured.

The dissection of fish included gutting and removing head and fins. Carcass efficiency was determined as proportion of carcass weight to whole body mass. Afterwards fish carcasses were chilled at temperatures between 0 and 4°C for 24 hours. Fillets with skin were cut out. Meat quality of the fillets taken from the left part of the carcasses was analyzed. The pH value and the color were evaluated. Muscle tissue acidification (pH) was measured 15 min post mortem ($pH_{15'}$) and after 24 h (pH_{24h}), with the use of a portable Handylab 2 apparatus (Schott Geräte Company) with a glass-calomel electrode. Fillet color was measured in the CIE L* system with the assistance of a Minolta CM – 5 spectrometer, where L* indicates color brightness. For further analytical purposes (water holding capacity - WHC, thermal drip and basic composition) fillet without the skin was employed. Fillet was minced and WHC was measured as free water content (%), according to the Grau and Hamm's method (1952) modified by Pohja and Niinivaara (1957).

Thermal drip was determined according to Janicki and Walczak (Znaniecki, 1983). The basic composition of fillet was assessed by determining the content of water, crude protein and intramuscular fat. Water content was determined according to the Polish standard PN – ISO 1442:2000. Content of crude protein was determined using the Kjeldahl method, according to PN – 75/A-04018 (apparatus Büchi B-324). Intramuscular fat content was determined using the Soxhlet method, consisting of ether fat extraction according to PN – ISO 1444:2000.

Growth parameters

Growth parameters were evaluated according to the following equations (Hardy and Barrows, 2002):

1. Specific Growth Rate (SGR) = $100 \cdot [(\ln w_t - \ln w_o) \cdot t^{-1}]$

w_o – initial fish weight (g); w_t- final fish weight; t-number of study days.

2. Feed Conversion Ratio (FCR):

$FCR = F_d \cdot (W_t - W_o)^{-1}$

F_d– weight of the diet (g), W_t – final fish weight (g), W_o – initial fish weight (g).

3. Protein Efficiency Ratio (PER):

$PER = (W_t - W_o) \cdot P^{-1}$

P – net weight (g) of protein in the diet (g), remaining symbols as in FCR equation.

4. Protein Retention index (PR):

$PR = (P_t - P_o) \cdot P^{-1}$

P_t – total protein weight of fish at the end of the trial (g), P_o – total protein weight of fish before the trial (g), P- total weight of protein in the diet (g).

5. Fat Retention index (FR):

$FR = (F_t - F_o) \cdot F^{-1}$

F_t – raw fat weight of fish at the end of the trial (g), F_o – raw fat weight of fish before the trial (g), F- raw fat weight in the diet (g).

6. Survival rate (SR):

$SR = (N_t \cdot N_o - 1) \cdot 100$

N_t – final number of fish (individuals), N_o – initial number of fish (individuals).

Statistical analysis

Data were evaluated using the Microsoft Excel spreadsheet, and analyzed with the statistical package Statistica 5 PL (StatSoft 2001). Data were subjected to MANOVA to test the effects of feed types and feeding frequencies on growth parameters. Following the analysis of variance, post-hoc group analysis was also performed. Homogeneous groups were determined by the T-Tukey test.

Results

Water temperature and dissolved oxygen

Changes in the average water temperature and oxygen content are presented in Fig. 1. Minimum temperature of the water was 15.3^{o}C and its maximum value was 24.8^{o}C. The lowest value of dissolved oxygen was 2.3 mg O_2/dm^3, and the highest was 8.2 mg O_2/dm^3.

Growth performance

Changes in body weight due to the diet and feeding technique are shown in Fig. 2. The mean weight of fish did not significantly differ among groups until the 60th day of the growth trial. Thereafter, the mean weight of the groups fed by hand was statistically lower than the mean weight of the groups fed by automated feeder. The differences lasted until the end of the trial.

Nutrient retention and survival of fish fed different diets and feeding technique are shown in Table 3 and Fig. 3. The difference in mean SGR between fish fed by hand and by automatic feeders was statistically significant and higher in fish fed by automatic feeder.

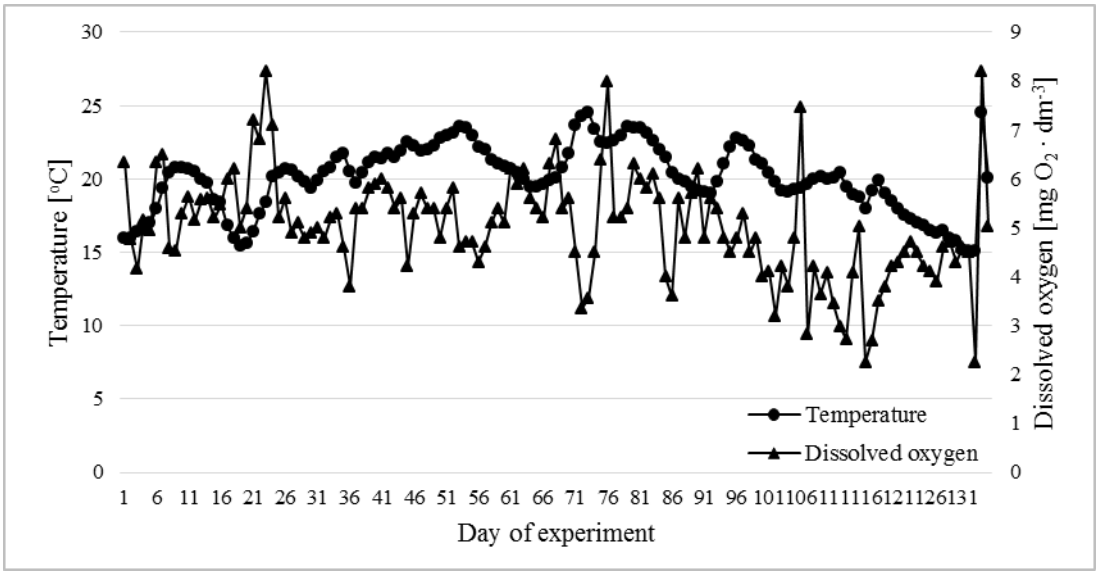

Figure 1: Daily changes of water temperature and dissolved oxygen concentration during growth test.

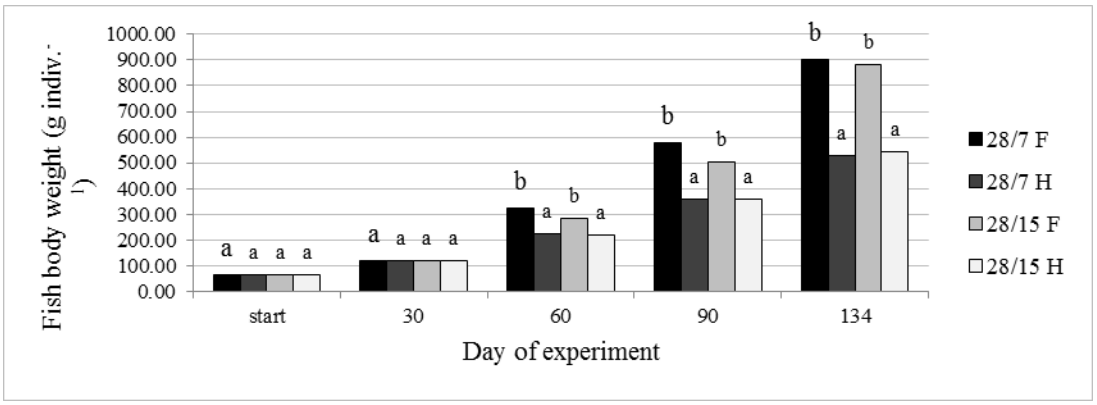

Figure 2: Changes in fish body weight[1] during the test (g · indiv.$^{-1}$).
[1]Values (are means ± standard deviation, SD) from three replicate groups of fish. Mean values in each row with different superscripts are significantly different (p<0.05)

The daily weight gain was similar in all groups until the third quarter. Thereafter, SGR increased in fish fed by automatic feeder. After the 90th day until the end of the trial SGR was significantly higher in the group 28/15 F. During the trial the value of FCR was significantly higher in fish fed by hand. The mean values of PER, PR and FR were higher in fish fed by the automated feeder. Mean individual weight, SGR, FCR, PER, PR and FR were not significantly different among groups. The survival rate was not significantly different among groups.

Table 3: Nutrient retention and survival of common carp fed different diets and feeding techniques during the growth trial[1].

Groups			
28/7 F	**28/7 H**	**28/15 F**	**28/15 H**
SGR (% d^{-1})			
1.98 ± 0.06^{b}	1.59 ± 0.03^{a}	1.97 ± 0.02^{b}	1.61 ± 0.04^{a}
FCR			
1.57 ± 0.1^{a}	2.05 ± 0.11^{b}	1.43 ± 0.07^{a}	2.02 ± 0.15^{b}
PER			
2.18 ± 0.19^{b}	1.48 ± 0.14^{a}	2.26 ± 0.22^{b}	1.53 ± 0.14^{a}
PR (%)			
30.39 ± 1.61^{b}	22.37 ± 1.51^{a}	31.73 ± 1.84^{b}	22.44 ± 1.12^{a}
FR (%)			
160.52 ± 5.25^{b}	44.01 ± 2.24^{a}	149.08 ± 6.11^{b}	47.87 ± 1.64^{a}
SR (%)			
96.0 ± 4.0^{a}	85.33 ± 6.11^{a}	90.67 ± 9.24^{a}	86.67 ± 10.07^{a}

[1]Values (are means ± standard deviation, SD) from three replicate groups of fish. Mean values in each row with different superscripts are significantly different ($p<0.05$)

Fish body composition, slaughter traits and meat quality

Dry matter and crude protein content did not change among groups during the trial. The content of crude lipids was significantly higher and the ash content was significantly lower after the trial in all groups (Table 4).

Analysis of the selected slaughter traits and meat quality is presented in the Table 5. Fish fed by automatic feeders had significantly higher body mass, carcass and fillet mass than fish fed by hand. There was no significant influence of feeding method on the analyzed meat quality characteristics ($p>0.05$). Meat from fish fed by automatic feeder was a little bit brighter and had higher fat content than fish fed by hand, but the differences were not statistically significant. Different diets did not have any influence on analyzed slaughter traits and meat quality characteristics ($p>0.05$).

Discussion

In the presented trial, dissolved oxygen, pH and water temperature in ponds were maintained within recommended ranges for common carp (Szumiec, 1998).

Growth was relatively fast (SGR= 1.59 – 1.98% x d^{-1}). Conversion of dietary nutrients was effective: FCR= 1.43 – 2.05 and PER= 1.48 – 2.26. All of these indicators were significantly higher in groups of fish fed by the automatic feeder. According to previous studies it may be caused by more frequent access to nutrients by fish during the day, which may result in the increase of nutrient absorption. Similar results were obtained by Silva et al. (2007) in a study conducted on tambaqui *Colossoma macropomum*.

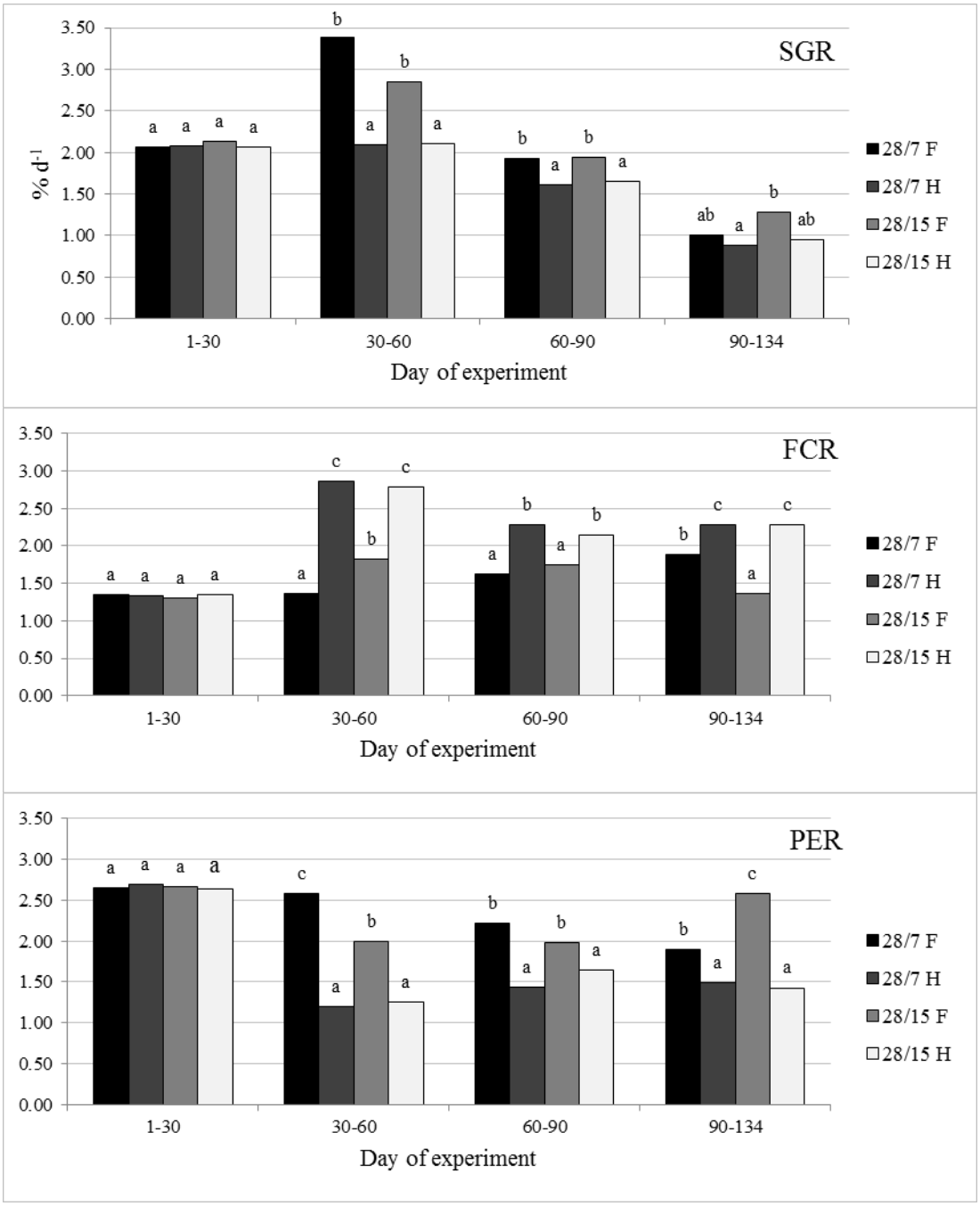

Figure 3: Changes in SGR, FCR and PER[1] during the trial.
[1]Values (are means ± standard deviation, SD) from three replicate groups of fish. Mean values in each row with different superscripts are significantly different (p<0.05).

Total meal rate (10% BW) divided into three meals during the day brought about better results on growth performance than the same rate divided into two meals. The same results were obtained by Sung-Yong and Venmahti (2015), in a study where three meals per day was the optimum feeding frequency.

Table 4: Effects of different diets and feeding techniques on chemical composition (g · kg^{-1} of wet matter) of common carp at the beginning and at the end of the trial[1].

Component	Initial	After the trial in groups			
		28/7 F	28/7 H	28/15 F	28/15 H
Dry matter	30.21 ± 0.9^{a}	33.52 ± 0.41^{a}	29.88 ± 0.23^{a}	31.88 ± 0.35^{a}	32.09 ± 0.27^{a}
Crude protein	11.6 ± 0.55^{a}	13.76 ± 0.31^{a}	14.58 ± 0.32^{a}	13.87 ± 0.29^{a}	14.27 ± 0.41^{a}
Crude lipid	7.51 ± 0.11^{a}	17.60 ± 0.17^{b}	14.71 ± 0.57^{b}	15.81 ± 0.31^{b}	15.54 ± 0.16^{b}
Ash	2.61 ± 0.13^{b}	1.57 ± 0.19^{a}	1.68 ± 0.18^{a}	1.95 ± 0.21^{a}	2.02 ± 0.22^{a}

[1]Values (are means ± standard deviation, SD) from three replicate groups of fish. Mean values in each row with different superscripts are significantly different (p<0.05).

Table 5: Effect of different diets and feeding techniques on selected slaughter traits and meat quality characteristics of common carp[1].

Analyzed traits	Groups			
	28/7 F	28/7 H	28/15 F	28/15 H
Mean fish body weight (g)	1015 ± 73^{a}	712 ± 66^{b}	894 ± 217^{ab}	694 ± 174^{b}
Mean carcass weight (g)	665 ± 48^{a}	457 ± 60^{b}	586 ± 151^{ab}	447 ± 115^{b}
Dressing percentage of carcass (%)	65.5 ± 1.4^{a}	64.0 ± 2.4^{a}	65.3 ± 1.7^{a}	64.4 ± 1.2^{a}
Fillet with skin weight (g)	472 ± 80.2^{a}	295 ± 41.1^{b}	411 ±84.8^{ab}	288 ± 60.5^{b}
Fillet with skin percentage in carcass weight (%)	70.8 ± 9.2^{b}	65.0 ± 9.6^{a}	71.2 ± 8.2^{b}	64.9 ± 5.4^{a}
$pH_{15'}$	6.43 ± 0.16^{a}	6.47 ± 0.09^{a}	6.47 ± 0.15^{a}	6.49 ± 0.15^{a}
pH_{24h}	6.32 ±0.05^{a}	6.32 ±0.03^{a}	6.31 ±0.08^{a}	6.21 ±0.09^{a}
Colour brightness - Y*	58.33 ± 3.56^{a}	55.43 ± 3.48^{a}	57.07 ± 1.30^{a}	56.05 ± 2.45^{a}
Thermal drip (%)	14.77 ± 4.08^{a}	14.27 ± 2.92^{a}	14.51 ± 2.76^{a}	12.86 ± 0.18^{a}
WHC - free water content (%)	36.13 ± 2.37^{a}	38.79 ± 1.87^{a}	40.39 ± 4.17^{a}	39.31 ± 4.99^{a}
Water content in meat (g · kg $^{-1}$)	737.7 ± 17.7^{a}	748.5 ± 20.3^{a}	746.2 ± 10.9^{a}	748,4 ± 15,9^{a}
Crude protein content in meat (g · kg $^{-1}$)	178.1 ± 2.4^{a}	174.0 ± 7.1^{a}	173.8 ± 2.7^{a}	173.4 ± 5.6^{a}
Fat content in meat (g · kg $^{-1}$)	66.8 ± 14.9^{a}	55.7 ± 19.0^{a}	60.5 ± 10.5^{a}	56.8 ± 13.3^{a}

[1]Values (are means ± standard deviation, SD) from three replicate groups of fish. Mean values in each row with different superscripts are significantly different (p<0.05).

A previous study (Wang *el al*., 1998) indicates that frequent feeding may lead to minimizing body mass variation. Dominant individuals have the opportunity to become satiated and as a result – less aggressive and subordinate individuals can feed more often. However, this effect was not supported by the study conducted by Zhou *et al*. (2003) on gibel carp *Carassius gibelio*, where feeding frequency had no effect on body size variation.

Plant based feeds may be little accepted by fish due to the bitter taste. In the study conducted by Slawski *et al.* (2011) little acceptance of feed with higher content of RPC (rapeseed protein concentrate) was observed. The feed intake was statistically lower in fish fed feeds with 66% and 100% of fish meal replaced with RPC. The solution may be using many different sources of protein which positively affect the feed taste (Dąbrowski nad Kozłowska, 1981). In our study, there were no symptoms of non-acceptance of feed by common carps.

Other important indicators connected with diet nutritive effectiveness are fat and protein retention. In the presented study, value of PR was significantly higher in groups 28/7 F and 28/15 F. In these groups the value of FR was very high: 160.52% and 149.08%, respectively. Accumulation of lipids in the fish body, mainly the reserve of fat accumulated around fish organs, may have a negative influence on the quality of meat (Zeitler *et al*., 1984; Murai *et al.,* 1985).

There were no significant differences in the initial and final crude protein and dry matter content in fish. Crude lipid content was higher at the end of the trial, and ash content was lower. There were no differences between the two types of diets or the two methods of feeding. This outcome is in agreement with the study conducted on juvenile gibel carp (Zhou *et al*., 2003), where ash content was significantly lower at the end of the trial and ash content decreased significantly with increasing feeding frequency.

The slaughter traits and meat quality analysis of common carp didn't show statistically significant differences between diets. However, according to some authors (Steffens and Wirth, 2007) diets containing plant components had an impact on the meat quality, sensory traits and fish body composition of common carp. These results are in agreement with Oberle *et al.* (1997), where 2-year old common carps fed with wheat (diet W), rice (diet R), maize (diet M) or lupin (diet L) showed better performance with respect to the group fed zooplankton. After 105 days of growth, the body weights of carp fed on cereal or lupin diets were similar (from 916 to 995g). Significantly lower weights were recorded in fish fed on zooplankton (659g). The share of fillet without skin, intestines and the remaining parts of the carcass were similar in carp fed on cereal and lupin diets, while in fish fed on zooplankton, the share of fillet was lower and the share of remaining parts of carcass were higher. Fish fed the diet containing maize had the highest content of fat in the body (14.5%). Slightly smaller amount of fat was found in carp fed on diets with wheat and rice, while in fish fed on lupin and zooplankton diets the fat content was the lowest - 10.7 and 8.2%, respectively. Protein content in the body for fish fed on cereal and lupin diets was 16.2 to 16.7%, while for those fed on zooplankton the protein content was significantly lower (15.5%).

Fish meat quality is determined by both genetic and environmental factors and by interactions between them (Fauconneau *et al.,* 1995; Boujard *et al*., 2004). Muscle tissue of rested and unstressed fish contains optimal glycogen level before slaughter.

In this study, the protein content ranged between 17.38 % and 17.81 %. These results are in agreement with Skałecki (2013). The pH values of the analyzed meat were similar in all groups and they were consistent with

the published data (Białowąs *et al.*, 2004; Puchała *et al*., 2005)

The literature suggests that the intramuscular fat is the most changing parameter (Buchtová and Ježek, 2011; Trbovic *et al*., 2013). Its content depends on many factors, the most important are feeding, diet supplementation and growth performance (Sadowski *et al*., 2000; Puchała and Pilarczyk, 2007; Davies and Gouveia, 2010; Tkaczewska and Migdał, 2012). The lipids in the fish meat are important, because they affect the flavor intensity (Grigorakis, 2007). Some researchers show relationship between nutrient digestibilites and feeding frequency– these authors (Yamamoto *et al*., 2007) used a low fat diet and high fat diet for *Cyprinus carpio*. In the case of high fat diet, increasing feeding frequency of diet decreases nutrient digestibility. In other studies (Nwanna *et al.* 2012) authors observed that effectiveness of methionine addition may interact with feeding frequency.

In our study, no significant differences were found in the intramuscular fat content between the two types of diets. This is in agreement with the study carried out by Boujard *et al*. (2004). The scientists tested three diets of low, medium and high fat content in commercially sized sea bass. They observed no significant differences in the muscle lipid. Additionally, they suggest that high dietary fat results in fat deposition primarily in the liver and perivisceral adipose tissues. Our earlier research on 2-year-old common carps (Mazurkiewicz *et al*., 2012) also showed that the addition of cold-pressed rapeseed cake in diets did not have any influence on the analyzed slaughter parameters and the meat quality.

In this study we show that the feeding technique has no significant effect on common carp rearing. The best results were obtained using feed administered continuously from automatic feeders. The main outcomes are:

- Increase in the individual weight of common carp juveniles from the initial weight of 63 g / pcs. to a final weight of 900 g / pcs.,
- Relative increase in body weight of fish at a rate of 2% per day,
- Favorable feed conversion ratio (about 1.5),
- High level of utilization of the nutrients by the common carp,
- High survival rate.

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