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THE UTILIZATION OF ALGAE WITH THE AIM TO INCREASE THE FATTY ACID CONTENT IN MUSCLE OF COMMON CARP (*CYPRINUS CARPIO* L.)

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Abstract

The aim of this study was to evaluate the efficiency of feeds with the addition of various algae and cyanobacteria. Common carp (average body mass of 19.6 ± 3.49 g) were randomly divided into 4 groups and fed a commercial feed (control group), the same commercial feed with the addition of 10 % of dry green algae of the genus *Chlorella* (chlorella group), dry biomass of algae from waste water treatment (algae group), and lyophilized toxic cyanobacterial biomass of the genus *Microcystis* (microcystis group). After 29 days of the experiment, standard indices for the assessment of feed utilization, external characteristics, fish condition, chemical composition of muscles and composition of fatty acids were measured. The feed variants with the addition of green algae (chlorella and algae groups) appeared to be nutritionally more favorable in our experiment. A higher content of PUFAs and total amount of fats (expressed in units of weight) were found in the groups of fish fed the green algae and algae from waste water treatment supplemented feed.

Keywords: fish, nutrition, sewage water, green algae, cyanobacteria

INTRODUCTION

Despite the various uses of algae in aquaculture, their most important application relates to nutrition. They are either the only component or is used as a food additive which supplies the basic nutrition, colors the salmonids‘ flesh or is related to other biological activities. Vast amounts of valuable antioxidants, proteins, carbohydrates and lipids are contained by the microalgae, thus making them a key food source for the development of zooplankton, all stages of bivalve mollusks, larval stages of gastropods and several fish species (Muller-Feuga, 2000).

The global trend of health-enhancing food forces fish culturists, and consequently also

fish feed producers to seek ways to increase the content of polyunsaturated fatty acids in fish meat. Polyunsaturated fatty acids (PUFAs) such as eicosapentaenoic acid (EPA) (20 : 5 n-3), docosahexaenoic acid (DHA) (22 : 6 n-3), and arachidonic acid (ARA) (20 : 4 n-6) are the most important ones in human nutrition. Their essential precursors are linoleic acid (LA) (18 : 2 n-6) and α-linolenic acid (LNA) (18 : 3 n-3). These acids perform a primary role in the prevention of many diseases (Glade, 2003).

The increase of the fatty acid content is attained by the addition of fish oil or plant oil into the feeds. Considering that fish oil is becoming increasingly costly and supply limited, we can assume that the content of fatty acids will be dependent on the plant ingredients of feeds (Spolaore *et al.*, 2006). When compared with fish oils, algae can provide more concentrated and clean sources of PUFAs. However, their contents vary in different species and environmental conditions, e.g. in growth mediums of different temperatures and mineral content. These conditions have a profound effect on the level and ratio of PUFA algal lipids. Algae can be used in aquaculture for enhancing the content of fish n-3 PUFA in both oil production and human consumption (Patil *et al.*, 2007).

Aquaculture facilities employ different techniques for mass production of microalgae, spanning from basic cultivation systems, i.e. ponds, raceways, aerated open carboys using natural light, to more complex systems, i.e. closed cylindrical tanks, vertical aerated column reactors functioning either in batch or continuous mode, or tubular and flat-plate photobioreactors, dependent on temperature control, artificial light and CO_2 enrichment (Zmora and Richmond, 2004).

One of the options is the biotechnology focused on the farming of microalgae using the waste waters from municipal and industrial waste water treatment facilities. The biomass of algae used for the post-treatment of waste waters (mainly decreasing the nitrogen and phosphorus content) is further utilized as a biofuel resource. Another option is to utilize this biomass as an additive in food for fish or other livestock (Feng *et al.*, 2011).

Our work study tested the influence of 10 % addition of green algae of the genus *Chlorella*, algae from waste water treatment, and toxic cyanobacterial biomass of the genus *Microcystis* into the feed formula on the fitness and fatty acid content of common carp.

MATERIAL AND METHODS

Experimental fish and design

Common carp (*Cyprinus carpio*) with an average body mass of 19.6 ± 3.49 g were obtained from the Pohorelice Fishery, placed into laminated circular tanks equipped with independent water recirculation at a volume of 0.3 m^3, and allowed to adapt to the experimental conditions for 14 days. Commercial granulated diet Skretting F1P B40 (Italy, 41 % proteins, 12 % fat, size 2.5 mm, batch number 463767) was provided during this period. After the adaptation period, the fish were randomly divided into 4 groups of forty specimens each (i.e. one control and three experimental groups). While the control fish were given the commercial feed (control group, dry matter 94.3 %, fat 12.3 %, crude protein 39.1 %, ash 5.6 %), the experimental carp were fed the same diet with the addition of 10 % dry green algae of the genus *Chlorella* (chlorella group, dry matter 94.9 %, fat 11.0 %, crude protein 40.7 %, ash 5.4 %) or dry biomass of algae from waste water treatment (algae group, dry matter 93.7 %, fat 11.4 %, crude protein 40.5 %, ash 5.6 %), or lyophilized toxic cyanobacterial biomass of the genus *Microcystis* (Microcystis group, dry matter 93.8 %, fat 10.6 %, crude protein 41.2 %, ash 5.6 %). The diets were prepared in the laboratory from a crushed commercial feed and shaped into 2.5 mm size particles. The tested diets were designed to be isoenergetic (20.2 MJ BE kg^{-1}, resp. 15.6 MJ DE kg^{-1}). The feeds were given to fish two times a day, at the daily amount corresponding to 2 % of the actual biomass. The study period lasted for 29 days. Water in these tanks (volume of 0.3 m^3) was completely changed daily and fish were exposed to a 12-h light/12-h dark photoperiod. The above experiment was performed in compliance with the laws on the protection of animals against cruelty (in compliance with Directive 2010/63/EU) as approved by the Ethics Committee of the Mendel University Brno, Czech Republic.

The chlorella biomass (*Chlorella kessleri*) was obtained from an open cultivation system from the Institute of Microbiology, Academy of Sciences, Trebon, Czech Republic (56.5 % proteins, 10.0 % fat). The algal biomass (*Chlorella vulgaris* 30 %, *Desmodesmus communis* 25 %, *Planktosphaeria gelatinosa* 10 %, *Scenedesmus acuminatus* 10 %, and others 25 %) was obtained from a waste water treatment facility, and cultivated for the experiment in a closed system (54.5 % proteins, 11.3 % fat).

The *Microcystis* biomass was obtained from a natural cyanobacterial bloom (monospecific population of *Microcystis aeruginosa*, 43.3 % proteins, 2.3 % fat), collected during the summer of 2007 from a breeding pond (Fishpond Management Pohorelice, Czech Republic). The concentration of total microcystins in the cyanobacterial biomass was 2,698 μg g^{-1} dry weights. Three dominant microcystin variants were present in the cyanobacteria with the following mean concentration: microcystin-RR 1462, microcystin-YR 96, and microcystin-LR 1,088 μg g^{-1} dry weights. The concentration of microcystins in the biomass was determined by reverse phase high-performance liquid chromatography with UV/VIS detection using established methods (Blaha and Marsalek, 2003). The microcystin contents were determined at the Research Centre for Environmental Chemistry and Ecotoxicology (RECETOX), Masaryk University in Brno.

Water quality analyses

A series of physicochemical properties [temperature, dissolved oxygen (DO), pH, conductivity, nitrite nitrogen ($N\text{-}NO_2$), nitrate nitrogen ($N\text{-}NO_3$), ammonia nitrogen ($N\text{-}NH_4$), phosphate phosphorus ($P\text{-}PO_4$), and chlorides (Cl^-)] were measured every day. Water properties determined during the experiments are presented in Tab. I.

Dissolved oxygen, pH, and temperature were measured using the portable HACH HQ40D meter (Hach Lange, Germany). Conductivity measurements were taken by the conductivity meter HI 98129 (HANNA Instruments, USA), and other chemical indices were determined using standard methods (APHA 1998).

Analyses of fish

Fish were killed by mechanical stunning and bled from a cut through gills. We used the default indices for the assessment of feed utilization, external characteristics, and fish condition (see Tab. II).

Muscle samples from six specimens of all groups were collected and transported to the laboratory for analytical processing. To evaluate the experiment, standard indicators of the chemical composition of muscles (dry matter, content of proteins, fats and ash) and the composition of fatty acids (FAs) were used. Fillets without skin from the left side were used for the analysis of muscles. Lipids were determined according to Soxhlet using a 12-h extraction by diethylether. The dry matter content was determined by drying the sample at 105 °C (for 24 h) up to a constant weight. The ash content was determined using the gravimetric method of incineration in an electric oven at 550 °C. The content of crude proteins was measured using the method by Kjehldahl with the use of the Kjeltec 23 apparatus (Tecator, Sweden). The fatty acid composition was determined using gas chromatography (HP 4890D chromatograph, Hewlett Packard, USA), following extraction with a mixture of methanol and chloroform (Folch *et al.*, 1957). Samples for the analysis of amino acids were hydrolyzed using oxidative acid hydrolysis by HCl (c = mol/dm^3). Subsequently, amino acids were determined using an AAA 400 unit (INGOS Prague, Czech Republic), sodium citrate buffers and ninhydrin detection (Kracmar *et al.*, 1998).

I: *The values of physicochemical parameters during the experiment (average ± standard deviation)*

	Unit	Control	Chlorella	Algae	Microcystis
Conductivity	μS cm^{-1}	1255 ± 865	1298 ± 915	1340 ± 1019	1058 ± 609
Temperature	°C	22.3 ± 0.5	22.0 ± 1.1	22.3 ± 0.9	22.0 ± 0.8
DO	%	94.9 ± 1.8	93.2 ± 2.1	93.1 ± 1.9	94.0 ± 1.3
pH		8.99 ± 0.10	8.95 ± 0.11	8.97 ± 0.09	9.02 ± 0.20
$N\text{-}NH_4$	mg L^{-1}	0.45 ± 0.46	0.49 ± 0.47	0.49 ± 0.49	0.56 ± 0.45
$N\text{-}NO_2$	mg L^{-1}	1.32 ± 1.31	1.20 ± 1.33	1.25 ± 1.41	1.15 ± 1.25
$N\text{-}NO_3$	mg L^{-1}	8.8 ± 0.4	9.1 ± 0.5	9.2 ± 0.7	8.8 ± 0.6
$P\text{-}PO_4$	mg L^{-1}	0.09 ± 0.08	0.11 ± 0.08	0.13 ± 0.06	0.11 ± 0.06
Cl^-	mg L^{-1}	220 ± 249	235 ± 264	238 ± 279	172 ± 186

DO dissolved oxygen

Statistical analysis

Statistical analyses were performed with Statistica for Windows® 9.0 (StatSoft, Tulsa, OK, USA). Results from different treatment groups were compared by one-way analysis of variance (ANOVA) and post hoc analysis of means using Tukey's test. The homogeneity of variances was tested by Levene's test. In these cases, nonparametric Kruskall-Wallis and Mann-Whitney tests were used for the comparison of treatment groups.

RESULTS

The aim of the present project was to evaluate the feed efficiency of feeds with the addition of various algae and cyanobacteria (Fig. 1). The results for the variants with *Chlorella*, algae, and the control were relatively equal. The most favorable food conversion ratio (FCR), food conversion efficiency (FCE), and specific growth rate (SGR) were obtained for the algae and chlorella variants. The other evaluating indicator, relative growth rate (RGR) showed worse results for the algae variant when compared to the Chlorella variant (Tab. II). The explanation for this is the higher weight of the fish stock in the algae variant at the beginning of the experiment. The least favorable results in all of the monitored indicators were recorded for the variant with the *Microcystis* cyanobacteria. Under the stated rearing conditions (hydrochemical properties, feeding technology, etc.), the addition of algae from the sewage water showed the best results with regards to the production indicators.

The group of fish fed with the addition of toxic cyanobacteria was evaluated as the most complicated considering indicators of the physiological condition of the fish organism, such as growth, the fat content in muscles, HSI, and VSI. The presented tables and graphs show that fish in this group had significantly the highest HSI (probably due to fat stored in the liver), higher VSI, and a lower fat content in muscles. In spite of the similar spectrum and amount of FAs in all feeds, particular groups of fish showed considerable differences in the fat content in muscles (Fig. 2). Lower values of PUFAs were shown in the fish prior to the experiment and in the fish fed with the addition of cyanobacteria. This was caused by the low fat content in

II: *The values of length-weight, fitness of the fish fry and production indicators (average ± standard deviation, N = 10). Significantly different indices compared to the control are marked by letters (p < 0.05).*

	Input	Control	Chlorella	Algae	Microcystis
TL (mm)	112 ± 5	119 ± 12	121 ± 6	122 ± 7	118 ± 8
SL (mm)	89.6 ± 4	95.1 ± 10	96.0 ± 6	95.4 ± 6	92.8 ± 8
H (mm)	30.5 ± 2	32.3 ± 3^{a}	34.6 ± 2^{a}	34.3 ± 2^{a}	31.3 ± 2^{b}
D (mm)	15.5 ± 1	15.8 ± 2	16.2 ± 2	15.8 ± 1	15.6 ± 2
W (g)	21.8 ± 3.4	23.7 ± 7.5	26.0 ± 4.0	25.5 ± 4.0	22.7 ± 4.2
Wx (g)	19.1 ± 3.02	20.7 ± 6.42	22.4 ± 3.28	22.1 ± 3.60	19.6 ± 3.66
Wh (g)	0.75 ± 0.25	0.70 ± 0.34	0.69 ± 0.17	0.68 ± 0.17	0.86 ± 0.25
Kf	3.01 ± 0.30	2.67 ± 0.16	2.94 ± 0.39	2.92 ± 0.15	2.85 ± 0.51
Kc	2.65 ± 0.28	2.34 ± 0.13	2.53 ± 0.25	2.52 ± 0.13	2.46 ± 0.43
VSI (%)	12.2 ± 0.97	12.4 ± 0.73^{a}	12.9 ± 0.39^{ab}	13.6 ± 1.11^{b}	13.7 ± 0.84^{b}
HSI (%)	3.89 ± 0.95	3.25 ± 0.66^{a}	3.04 ± 0.42^{a}	3.11 ± 0.77^{a}	4.43 ± 0.99^{b}
FCR	–	2.47	2.62	2.30	6.23
FCE	–	0.41	0.38	0.43	0.16
SGR (% D^{-1})	–	0.75	0.71	0.78	0.30
RGR (%)	–	21.3	22.8	22.1	9.2
FCR/SGR	–	3.28	3.70	2.97	20.58

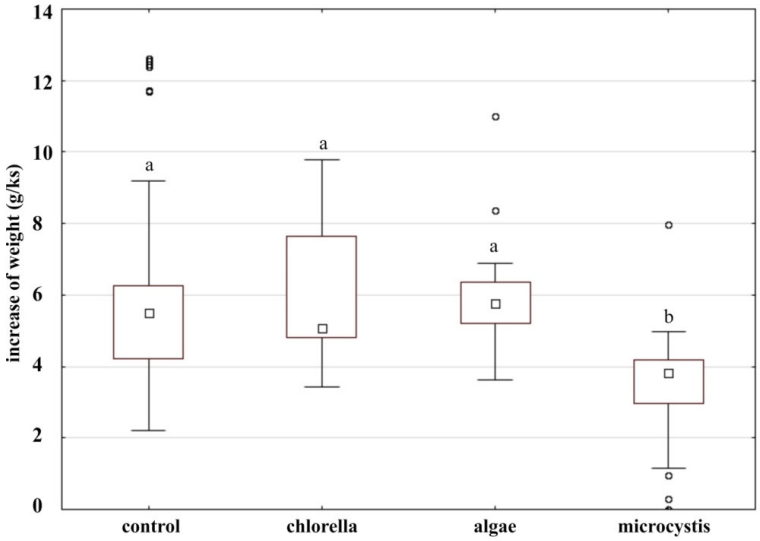
TL (Total Length), SL (Standard Length); H (height of fish); D (width of fish), W (weight of fish), W_x (weight of fish without visceral complex) W_h (weight of hepatopancreas), FCR (Food Conversion Ratio), FCE (Food Conversion Efficiency), SGR (Specific Growth Rate), RGR (Relative Growth Rate), K_f (Fulton's coefficient), K_c (Clark's coefficient), HSI (HepatoSomatic Index), VSI (Viscerosomatic Index)

the muscle. Conclusive differences in the FA content were observed in n-3 PUFAs which are the most important FA group for human nutrition. A higher content was reached in the group of fish fed with the addition of green algae (Tab. III).

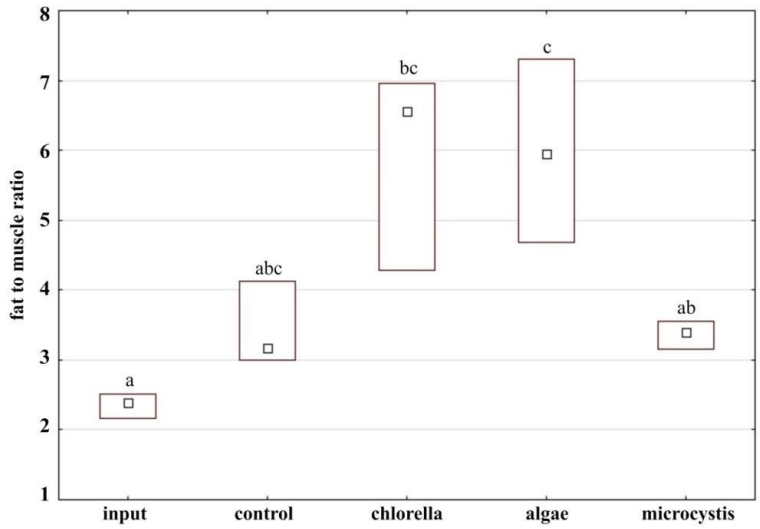
DISCUSSION

Many biotic and abiotic conditions, such as the species of fish, its age, rearing technology, environmental conditions, nutrition, stress, etc. have a strong effect on the composition of fish muscles (Fajmonova *et al.*, 2003; Mraz and Pickova, 2011). The contents of fatty acids is strongly affected by the pattern of lipids in their food, in all fish species. The oil content, especially the n-3 unsaturated fatty acids, results in the high dietetic value of fish muscles (Steffens, 1997; Kminkova *et al.*, 2001; Kowalska *et al.*, 2015).

The total amount of lipids in the control group and in the group with the addition of cyanobacteria was lower in our experiment, ranging from 3 to 4 %. On the contrary, the results in the groups with the addition of algae (chlorella and green algae) showed a higher content of lipids in muscles (5–7 %). Higher percentage of PUFAs was shown



1: *The growth of the fish during the feeding test (g). Box includes the 25th to 75th percentiles, with the middle point representing the median and the data point showing the extremes. Letters indicate statistical significance among groups (P < 0.05).*



2: *The fat content (%) in muscle of tested fish. Box includes all measurements, with the middle point representing the median. Letters indicate statistical significance among groups (P < 0.05).*

only in the fish at the beginning of the experiment and in the group of fish with the addition of cyanobacteria which was caused by a low fat content in muscles. Higher MUFA concentrations and lower PUFA concentrations were observed in the feeds and in most of the monitored groups. This composition corresponds with fish fed by feed mixtures or by cereals. In fish from natural waters that feed on natural food or in fish fed by feeds with a higher fish fat ratio, the opposite results have been documented (Steffens, 1997; Steffens and Wirth, 1997; Mraz and Pickova, 2011).

In recent years, the aquaculture industry has succeeded in reducing the content of fish meal and fish oil in the feeds of aquatic animals, especially fish. Finding and testing alternate protein and lipid sources is important to the aquatic feed industry (Kiron *et al.*, 2012). The fish meal and fish oil are mostly substituted by various plant components such as rapeseed, linseed, and hempseed which are easily available and economically feasible (Mraz *et al.*, 2012). Common carp is an omnivorous species, which can consume great amounts of plant

III: *The fatty acids content (g kg^{-1}) in fish muscle (average ± standard deviation). Letters indicate statistical significance among groups ($p < 0.05$).*

	Input	Control	Chlorella	Algae	Microcystis
C14 : 0	0.10 ± 0.01	0.14 ± 0.03	0.21 ± 0.07	0.27 ± 0.13	0.12 ± 0.02
C16 : 0	1.58 ± 0.17	2.36 ± 0.47	3.81 ± 1.20	4.36 ± 1.46	2.00 ± 0.24
C16 : 1n-7	0.49 ± 0.04	0.60 ± 0.19	0.91 ± 0.31	1.35 ± 0.63	0.50 ± 0.23
C18 : 0	0.57 ± 0.07	0.75 ± 0.07	1.22 ± 0.39	1.29 ± 0.33	0.79 ± 0.07
C18 : 1n-9	1.77 ± 0.42	5.08 ± 1.47	8.15 ± 3.06	9.95 ± 4.80	4.08 ± 1.13
C18 : 1n-7	0.38 ± 0.02	0.55 ± 0.10	0.87 ± 0.30	1.11 ± 0.42	0.52 ± 0.07
C18 : 2n-6	0.85 ± 0.15	2.67 ± 1.19	3.80 ± 1.46	4.33 ± 2.05	2.08 ± 0.37
C18 : 3n-6	0.02 ± 0.00^{a}	0.04 ± 0.01^{ab}	0.05 ± 0.01^{ab}	0.07 ± 0.03^{b}	0.03 ± 0.01^{ab}
C18 : 3n-3	0.27 ± 0.01	0.50 ± 0.11	0.89 ± 0.36	1.24 ± 0.63	0.66 ± 0.19
C18 : 4n-3	0.03 ± 0.00	0.03 ± 0.00	0.06 ± 0.02	0.09 ± 0.04	0.05 ± 0.00
C20 : 1	0.19 ± 0.02	0.47 ± 0.12	0.82 ± 0.32	0.89 ± 0.34	0.36 ± 0.04
C20 : 4n-6	0.60 ± 0.05	0.68 ± 0.11	1.03 ± 0.29	0.92 ± 0.08	0.67 ± 0.06
C20 : 4n-3	0.07 ± 0.05	0.08 ± 0.01	0.12 ± 0.04	0.14 ± 0.04	0.09 ± 0.02
C20 : 5n-3	0.50 ± 0.05^{ab}	0.39 ± 0.04^{a}	0.70 ± 0.17^{ab}	0.75 ± 0.11^{b}	0.50 ± 0.07^{ab}
C22 : 4n-6	0.07 ± 0.01	0.08 ± 0.02	0.10 ± 0.03	0.11 ± 0.02	0.06 ± 0.01
C22 : 5n-6	0.01 ± 0.00^{a}	0.02 ± 0.00^{bc}	0.02 ± 0.01^{abc}	0.02 ± 0.00^{c}	0.01 ± 0.00^{ab}
C22 : 5n-3	0.27 ± 0.01	0.27 ± 0.03	0.46 ± 0.12	0.45 ± 0.02	0.29 ± 0.03
C22 : 6n-3	0.83 ± 0.09	0.97 ± 0.04	1.61 ± 0.45	1.60 ± 0.15	1.32 ± 0.29
SFA	2.25 ± 0.25	3.25 ± 0.55	5.25 ± 1.64	5.92 ± 1.91	2.91 ± 0.33
MUFA	2.63 ± 0.46	6.23 ± 1.75	9.93 ± 3.67	12.40 ± 5.85	5.10 ± 1.41
PUFA	3.51 ± 0.17	5.75 ± 1.31	8.85 ± 2.88	9.72 ± 2.68	5.76 ± 0.78
Σ (n-6)	1.54 ± 0.20	3.49 ± 1.25	5.00 ± 1.76	5.45 ± 2.02	2.85 ± 0.37
Σ (n-3)	1.97 ± 0.16^{a}	2.24 ± 0.12^{a}	3.84 ± 1.14^{a}	4.27 ± 0.66^{b}	2.91 ± 0.52^{a}
Σ (n-3)/(n-6)	1.30 ± 0.23	0.71 ± 0.19	0.79 ± 0.08	0.86 ± 0.21	1.03 ± 0.17

PUFA (Polyunsaturated fatty acids), MUFA (monounsaturated fatty acids), SFA (saturated fatty acids)

carbohydrates and is capable of using this energy more efficiently, when compared to carnivorous species (Kiron *et al.*, 2012).

Another option for replacing fish meal in fish feed mixtures is to utilize various species of microalgae. Considerable efforts have been made to promote the use of microalgae in human food. Significant efforts are being made for the promotion of use of microalgae in human consumption. Nevertheless, the high costs of production and risks of toxicological contamination are limiting the application of algae to expensive „health foods". Thus far, the use of microalgae cultures has been a more successful food source and feed additive in the commercial production of aquatic animals, either freshwater or marine (e.g. rearing larvae and juveniles of many commercially important mollusks, penaeid prawn larvae, crustaceans, and fish) (Mata *et al.*, 2010). Knowing that microalgal proteins' amino acid profiles are comparable to those of other reference food proteins, they could make a perfect substitution for fish in the aquatic feed. Consequently, algae will most likely substitute part of the presently used fish feed, namely fish oil and fish meal, with a less sustainable production. Bearing that in mind, microalgae will probably be used as an admixture in fish feed. (Taelman *et al.*, 2013).

Compared to the additives of common agricultural crops (flax, rape), the utilization of microalgae in feed mixtures has many advantages. It is a natural food taken by fish either directly, or through the food chain. Depending on the environmental conditions, cyanobacterial biomass or algal biomass with a high content of fatty acids (EPA and DHA) can be produced. These contain a range of minerals and trace elements and, furthermore, the production does not compete with other agricultural crops grown on arable lands. Experiments with algal compound additives in fish feeds have reported the possibility of utilization of up to 20 % of cyanobacterial or algal addition without any negative influence on the fish organism (Olvera-Novoa *et al.*, 1998; Guroy *et al.*, 2007). Algae with a higher PUFA ratio can even increase the ratio of these fatty acids in fish muscles (Diler *et al.*, 2007).

In our experiment, we chose to test the additives of planktonic cyanobacteria *Microcystis* sp., Chlorella monoculture, and the mixture of mainly green algae from a sewage water treatment lagoon. The use of cyanobacteria in fish feed is problematic due to their low digestibility. Keshavanath *et al.* (1994) observed decreasing ingestion of cyanobacteria *Microcystis aeruginosa* by fish with an increasing toxin content.

Changes in the muscle lipid content of fish were observed in fish (*Oreochromus niloticus*) capable of efficiently digesting cyanobacteria (Tadesse *et al.*, 2003). Compared to green algae and diatoms, cyanobacteria of the genus *Microcystis* have a lower proportion of EPA, and also a lower total amount of fatty acids (Ahlgren, 1992). The results of our experiment indicate a negative effect of cyanobacteria on the composition of fatty acids in muscles of common carp, which is also confirmed by the results of other authors (Mares *et al.*, 2009). Therefore, cyanobacteria are not suitable for use as sources of lipids and proteins in aquaculture.

Even though algae have a number of uses in aquaculture, their main uses are nutritious. They present one of the most important food sources in aquaculture, due to their nutritional value and as a result of their ability to produce and store significant amounts of PUFAs (Taelman *et al.* 2013). Different techniques have been used by aquaculture systems for a large scale production of microalgae, e.g. ponds, raceways, aerated open carboys with a natural source of light, closed cylindrical tanks, vertical aerated column reactors or tubular and flat-plate photobioreactors (Zmora and Richmond, 2004). The obstacle for a more wide-spread use of microalgae in fish feed is the high production price of the dry matter of algae in those systems. One of the more economical ways is to use the algal biomass from sewage water treatment lagoons. A mixed culture of green algae, or algae of the genera *Chlorella* and *Desmodesmus* are most commonly used for this treatment (Aslan and Kapdan, 2006; Samori *et al.*, 2013). The cultivation of microalgae with wastewater as a medium is a promising method of producing algal lipid for aquaculture (Feng *et al.*, 2011).

The feed variants with the addition of green algae (*Chlorella* and algae) appeared to be nutritionally more favorable in our experiment. Evident differences were detected in the FA content in n-3 PUFAs, which are the most important for human nutrition. A higher content of PUFAs and total amount of fats (expressed in units of weight) were noted in the group of fish fed the green algae-supplemented feed.

CONCLUSION

The addition of 10 % of cyanobacterial or algal component to the complete feed formulas for common carp showed significant changes in some length/size and nutritional values, and in the content of fatty acids. In the case of the application of feed with the addition of toxic cyanobacteria, deterioration of the physiological state of fish was documented. The majority of the monitored values were better in fish in the green algae variant compared to the control group. The use of algae from a sewage water treatment lagoon as a component of fish feed with the aim to increase the lipid content with a higher percentage of PUFAs in fish muscles seems to be a real possibility. However, there is still a risk of contamination of algae with toxic substances from waste waters, such as heavy metals.

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