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Effects of different European catfish feeds on production parameters and water quality in limnocorrals

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ABSTRACT

Fishmeal replacement in diets for intensive aquaculture has become a high priority area for the global aquaculture industry. In this study, a 95 day long experiment was carried out between June and September with one-year-old European catfish (Silurus glanis) (72.7 ± 1.3 g initial weight). The fish were fed with 6 isocaloric and isoproteic (35% CP) feeds in three replications. Feeds differed according to the main protein source as follows: fish meal (FM), meat meal (AP), corn (SC), wheat (SW), wheat treated with Axtra XB xilanase (SW-A), wheat treated with Belfeed B 1100 MP xilanase (SW-B). FM diet was regarded as the control. The mean body weight rose from 72.7 ± 1.3 g to 325.9 ± 14.2 g. The mean body weights of AP and FM groups differed significantly from the SW, SW-A and SW-B groups. The SGR range was significantly higher in the AP and FM diets. The feed conversion ratio of AP group did not differ from the FM group significantly. Significant differences were found among the water quality parameters in case of total suspended solids (TSS). Significant differences were also found among FM, AP and SW-A treatments in the Kjeldahl-N content of the sediment at the end of the experiment. According to the results processed animal protein is a suitable alternative instead of fish meal. Enzymatic supplementations have not been as useful as expected. Its reason needs further investigation.

(Keywords: European catfish, fish meal, animal protein, limnocorral)

INTRODUCTION

European catfish (*Silurus glanis*), is the largest European freshwater fish. It is native to Eastern Europe and West Asia, it can be found in the larger rivers (The Danube, Volga catchment area), and lakes. It has been introduced to a number of Western European countries, France, Italy, Spain, and the UK. Due to its high growth potential and its efficient feed conversation (*Heymann*, 1990), it is successively produced in ponds (*Mareš et al.*, 1996, *Ulikowski et al.*, 2003), cages (*Filipiak et al.*, 1997, *Ržaničanin et al.*, 1984) and recirculation systems (*Linhart et al.*, 2002). Many previous studies have dealt with the growth of the catfish. Jungwirth (1986) carried out feeding experiment with zooplankton and trout feed at different temperatures in different age of groups. *Manthey et al.* (1988) bred three Siluriformes species (*Silurus glanis, Ictalurus punctatus, Clarias gariepinus*) from larvae for two years with traditional trout feed, and the composition of the fillet was investigated by sensory and chemical measurements. The results of catfish feeding experiment in polyculture have been presented by *Stevič* (1989), who used Trouvit feed in his studies. To our knowledge, no information is available on the study of replacement of fish meal (FM) with processed animal protein (PAP) in European catfish. Accordingly, the aim of this study was to assess the potential of using PAP versus soybean meal (SM) as FM substitute protein in practical diets of *Silurus glanis*. Changing of water quality traits during the trial was also analyzed.

MATERIAL AND METHODS

Experimental fish

In total 144 specimens of European catfish were applied in 72.7 ± 5.2 g initial weight. Fish were originated from a local fish farm, reared on artificial feeds in pond monoculture. 8-8 individuals were stocked in each enclosure (0.12 $kg \cdot m^{-3}$). Two weeks of acclimatization period were used before the experiment.

Experimental system

The 95 day long experiment was carried out between June and September at Research Institute for Fisheries and Aquaculture, Szarvas, Hungary. 18 cylinder shaped limnocorrals, with 2 m diameter and 5 m^3 volume, were used. These microcosms were made of non-transparent polyethylene and were open towards the bottom and the sky as well. At the bottom, wire net was burrowed into 20 cm deep to avoid escaping fish. The enclosures were set up in a 700 m^2 earthen pond. The pond was drained and treated with $Ca(OH)_2$ (357 $kg \cdot ha^{-1}$) prior to the experiment. Water originated from Körös River, but the flow through was ceased during the trial. Aeration was maintained in each limnocorral.

Experimental diets

The experimental feeds were designed and formulated to meet or exceed the demand of a close relative species, the channel catfish, *Ictalurus punctatus* (*Robinson and Li,* 1999*; Robinson et al.*, 2001), as the nutrient requirements of European catfish are not determined yet. Diets were isonitrogenous and the amino acid composition was very similar, but the source of protein was different: animal and plant, or all plant sources. Six different practical diets (FM, AP, SC, SW, SW-A, SW-B) were fed proximate composition of which is shown in *Table 1*.

FM diet was regarded as the control, as it contained fish meal. AP diet contained some rendered animal protein, but no fish meal. SC and SW were the vegetable diets and contained no animal ingredients. These two feeds differed as besides soybean they contained mainly corn or wheat. SW-A and SW-B were practically the same as SW, but xylanase enzyme (Belfeed B 1100 MP, Beldem S. A., Belgium) were added to the SW-A, and beta-glucanase (Axtra XB, Danisco Animal Nutrition, Marlborough, UK) to SW-B in 100 $mg \cdot kg^{-1}$.

Fish were fed using automatic belt feeders. Daily ration was 1.3% initially which was raised to 2% by the end. All treatments were applied in triplicates.

Chemical analysis

Water temperature, DO level ($mg \cdot L^{-1}$), oxygen saturation (%), conductivity ($\mu S \cdot cm^{-1}$) and pH (WTW Multi 3430, WTW GmbH., Germany) were measured multiple times per week. Water samples were taken from the pond and each enclosure before and during the experiment bi-weekly. Water samples were analyzed, NO_2-N, NO_3-N, TAN, TIN, TON, PO_4-P (Quickhem 8500, Hach, Loveland, USA) TP, TN (Lange Gaminede P, N), Chl-a (DR/4000U, Hach, Loveland, USA) TSS and concentration of metals (ICAP 6000, ICP-OES, Thermo Fisher Scientific Inc.) were measured. Samples were taken from the sediment also before and after the experiment. Besides of upper ones Kjeldahl-N (Büchi B-324) and metal content (ICAP 6000, ICP-OES, Thermo Fisher Scientific Inc.) were determined from these samples.

Table 1.

Ingredients and proximate composition of experimental diets

	Diet					
	FM	AP	SC	SW	SW-A	SW-B
Ingredients (g·100g^{-1})						
Soybean meal, solvent extracted	30.30	25.05	40.00	49.74	49.74	49.74
Fishmeal	19.00	0.00	0.00	0.00	0.00	0.00
Meat meal	0.00	17.00	0.00	0.00	0.00	0.00
Corn	26.50	27.14	16.48	0.00	0.00	0.00
Corn gluten	12.20	18.80	19.10	15.44	15.44	15.44
Wheat	10.00	10.00	10.00	30.00	30.00	30.00
Canola meal, solvent extracted	0.00	0.00	10.00	0.00	0.00	0.00
Mono-calcium phosphate	0.00	0.00	1.30	1.30	1.30	1.30
DL- Methinonine	0.00	0.10	0.00	0.07	0.07	0.07
L-lysine	0.00	0.54	0.42	0.35	0.35	0.35
Sunflower oil	1.50	0.87	2.20	2.60	2.60	2.60
Vitamin- and Mineral Premix*	0.50	0.50	0.50	0.50	0.50	0.50
Actual composition (g·100g^{-1})						
Dry matter	89.40	90.70	88.90	89.50	89.50	89.50
Moisture	10.60	9.30	11.10	10.50	10.50	10.50
Crude protein	34.55	35.6	34.65	35.5	35.5	35.5
Lipid	5.05	5.15	4.39	4.49	4.49	4.49
Fibre	0.44	1.52	3.62	3.19	3.19	3.19
Ash	7.10	5.90	5.60	5.70	5.70	5.70

*Vitamin A: 400 000 IU·kg^{-1}, Vitamin D_3: 200 000 IU·kg^{-1}, Vitamin E: 6000 mg·kg^{-1}, Vitamin K_3: 918 mg·kg^{-1}, Vitamin B_1: 500 mg·kg^{-1}, Vitamin B_2: 1200 mg·kg^{-1}, Vitamin B_6: 1000 mg·kg^{-1}, pantothenic acid: 3000 mg·kg^{-1}, folic acid: 500 mg·kg^{-1}, Vitamin C: 10 000 mg·kg^{-1}, Ca: 22.8 g·100g^{-1}, Fe: 6000 mg·kg^{-1}, Zn: 40 324 mg·kg^{-1}, Mn: 5022 mg·kg^{-1}, Cu: 1000 mg·kg^{-1}, Se: 22.5 mg·kg^{-1}, I: 496 mg·kg^{-1}, antioxidant: 2000 mg·kg^{-1}.

Calculations and statistical analysis

Fish were measured individually with 0.1 g precision. Weight gain (WG), feed conversion ratio (FCR), protein efficiency ratio (PER), specific growth rate (SGR) and coefficient of variance (CV) were calculated from the data as below:

$$\text{WG (g}\cdot\text{fish}^{-1}) = W_t/N_t - W_0/N_0$$

$$\text{FCR (feed}\cdot\text{gain}^{-1}) = I/\ (W_t - W_{0\,+}\,W_d)$$

$$\text{PER (gain}\cdot\text{consumed protein}^{-1}) = WG/P$$

$$\text{SGR (\%}\cdot\text{day}^{-1}) = (\ln W_t - \ln W_0)/t\cdot 100$$

$$\text{CV (\%)} = SD_{bw}/mean_{bw}\cdot 100$$

where I(g) is the total amount of offered feed, W_0(g) is the total initial body weight, W_t(g) is the total final body weight, W_d(g) is the dead fish weight, N_0 is the number of fish at the beginning of trial, and N_t is the number of fish at the end of it, P(g) is the amount of consumed protein, t(d) is the duration of the trial and bw is body weight.

Shapiro-Wilk test and Kolmogorov-Smirnov probe were used to test normality, and Levene's test was applied to test the homogeneity of variances. Means were compared by one-way analysis of variance (ANOVA) followed by LSD post hoc test in cases of normal kurtosis. Where distribution was not normal, non-parametric Kruskal-Wallis test was used for comparing means. Significance was accepted at P<0.05.

RESULTS

At the beginning of the trial, there were no significant differences between mean body weights of the different groups (*Figure 1*). During the 95 days the mean body weight rose from 72.7 ± 1.3 g to 325.9 ± 14.2 g ($mean_{bw}$ ± S. E.). By the end of the trial mean body weights of AP and FM groups differed significantly from the SW, SW-A and SW-B groups. However, the final mean weight of SC group did not differ significantly from any of the other treatments.

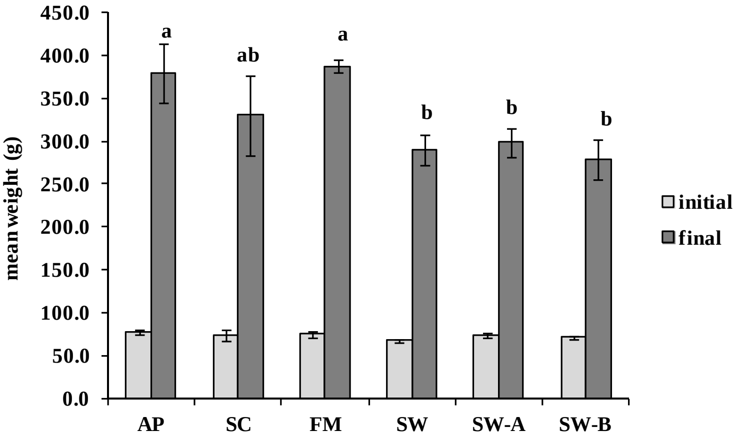

Figure 1.

Initial and final mean body weights of European catfish

(Different superscripts indicate significant differences)

Results of the experiment including data of growth and feed efficiency are shown in *Table 2*. Weight gain for the whole experimental period was the highest in FM and AP groups, while it was the lowest in the case of the two enzyme treated diets. Weight gain of SW and SC differed significantly from FM, but not from AP group. For the total experimental period, SGR ranged from 1.43 (SW-B) to 1.73 (FM). Considering this parameter the enzyme-treated diets showed significantly poorer achievements than the AP and FM diets. The animal protein containing feeds did not differ significantly from each other.

Table 2.

The performance traits of fish (mean ± S.E.)

Treatments	Weight gain (%)	SGR	FCR	PER
FM	$418.28^{a} \pm 20.95$	$1.73^{a} \pm 0.04$	$1.13^{a} \pm 0.06$	$2.57^{a} \pm 0.08$
AP	$391.68^{ab} \pm 34.80$	$1.67^{a} \pm 0.07$	$1.29^{ab} \pm 0.02$	$2.17^{ab} \pm 0.02$
SC	$348.88^{abc} \pm 22.54$	$1.58^{ab} \pm 0.05$	$1.45^{ab} \pm 0.06$	$1.99^{b} \pm 0.06$
SW	$330.08^{bc} \pm 18.88$	$1.53^{ab} \pm 0.04$	$1.53^{b} \pm 0.11$	$1.85^{b} \pm 0.07$
SW-A	$303.08^{c} \pm 25.62$	$1.47^{b} \pm 0.06$	$1.55^{b} \pm 0.12$	$1.84^{b} \pm 0.10$
SW-B	$290.55^{c} \pm 25.84$	$1.43^{b} \pm 0.06$	$1.61^{b} \pm 0.11$	$1.79^{b} \pm 0.13$

Mean values bearing different superscripts in a column are significantly ($p<0.05$) different

FCR varied between 1.13 and 1.61. Fish of the SW-B group presented the highest and the lowest was observed in the FM group respectively. The feed conversion of AP group did not differ from the FM group significantly. Protein utilization was found the best in the FM group with the value of 2.57 and lowest in the SW-B group (1.79). Regarding PER, there were significant differences found between FM group and all the animal protein free groups, but the AP group differed neither from FM nor from the plant protein based diets.

Water quality

Dissolved oxygen (DO) levels ranged between 6.2 and 7.0 mg l^{-1} in the treatments. The highest value was in treatment SW-B, and lowest was in treatment SW. The changes were similar among the treatments. In the first and the last period of the experiment DO levels increased and decreased in the middle period of the experiment. DO ranging from 2.73 to 12.33 mg l^{-1}. The lowest values were measured (2.16 – 3.13 mg l^{-1}) in all tanks 4th September. pH was relatively stable during the experiment, ranged between 6.5 and 8.8. The average water temperature (WT) was 23.23±3.27 °C during the experiment. The highest temperature was measured in the first decade in August. WT was decreased from August to the end of the experiment. The temperature ranged from 15.3 to 28.2 °C.

Samples were taken from the refill water, so the first values were agreed in the treatments. The concentration of total nitrogen (TN) changed similarly in all treatments during the culture period (*Fig. 2a*).

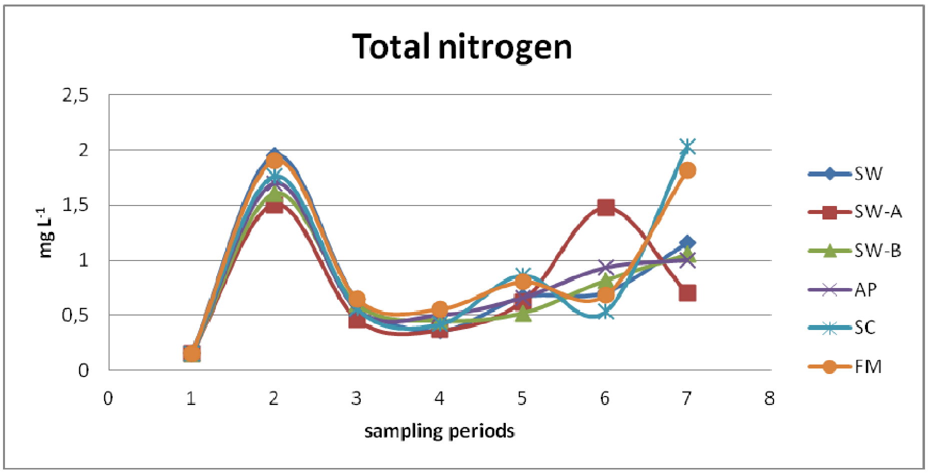

Figure 2a.
The concentration of total nitrogen in all treatments during the trial

Treatment SC and FM had the highest TN level (2.03 and 1.82 mg l^{-1}) at the end of the experiment. The values of total ammonia nitrogen (TAN) changed periodically during the experiment (*Fig. 2b*).

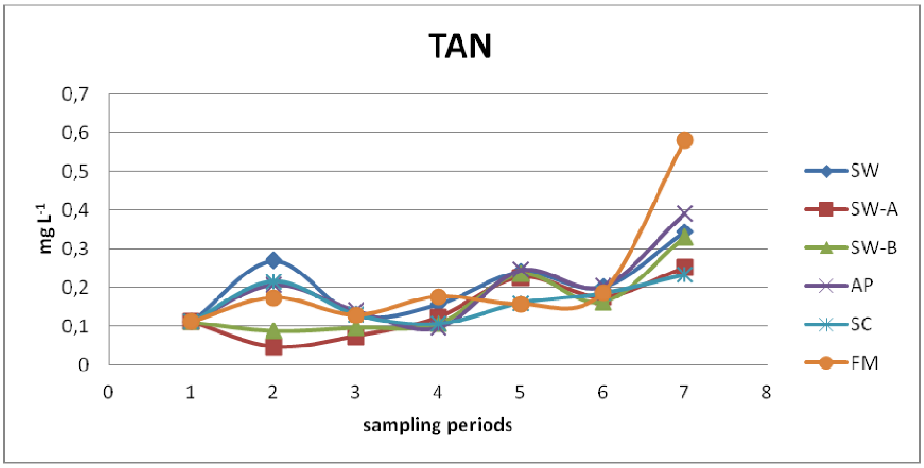

Figure 2b.
The concentration of total ammonia nitrogen in all treatments during the trial

At the end of the experiment, the values were higher in all treatment than at the start of the experiment. The highest value was in treatment FM (0.579 mg l^{-1}) at the end of the experiment. We did not find significant difference in this parameter. The values of nitrite-nitrogen (NO_3-N) are shown in *Figure 2c*.

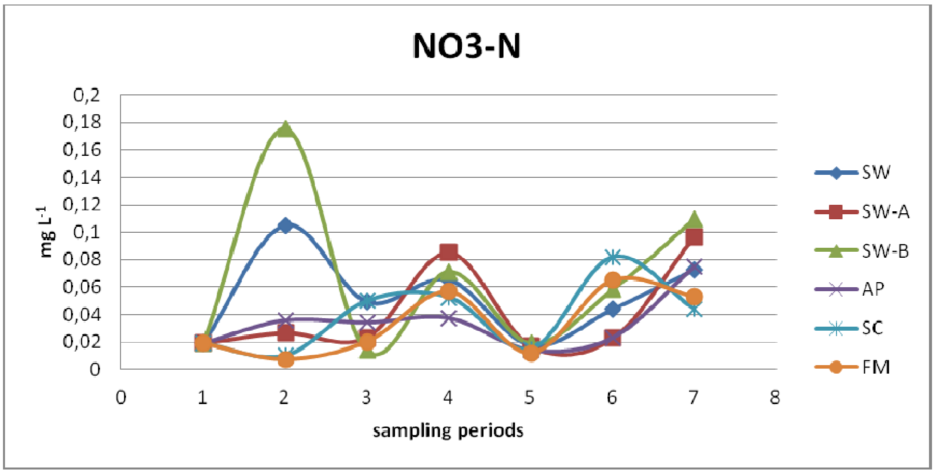

Figure 2c.
The concentration of nitrate-nitrogen in all treatments during the trial

The concentration of NO_3-N in treatment SW and SW-B was very high (0.175 and 0.105 mg l^{-1}) at the second sampling date. The values changed periodically and more or less contrarily to TAN in the middle of the experiment. The concentration increased in all treatments to the end of the experiment. Treatment SW-A and SW-B had the highest NO_3-N level (0.1 and 0.11 mg l^{-1}), treatment SC had the lowest NO_3-N level (0.04 mg l^{-1}) at the end of the study. We did not find significant difference between the treatments. The values of orthophosphate (PO_4-P) increased the first time of the experiment in all treatments (*Fig. 2d*).

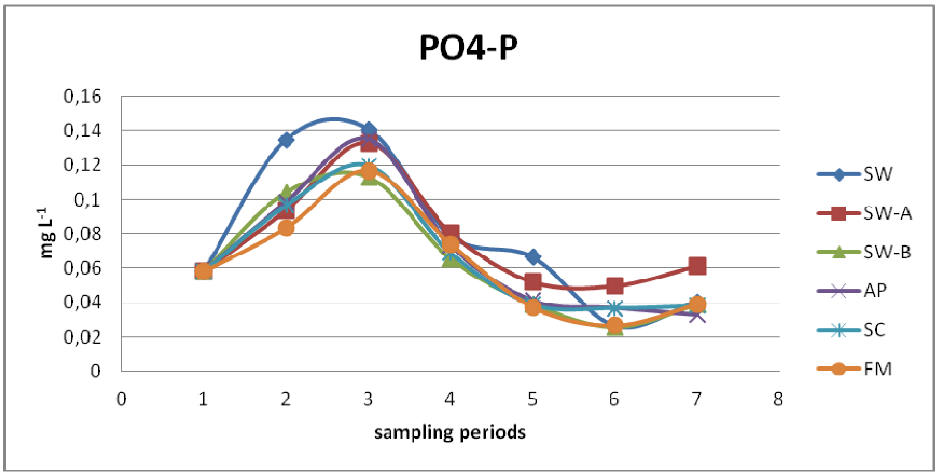

Figure 2d.
The concentration of orthophosphate in all treatments during the trial

From early July the values decreased in all treatments until September. The end of the experiment the concentrations increased slightly. We did not find significant difference between the treatments. The concentration of total phosphorus (TP) was changed similarly in the treatments in the first half period of the experiment (*Fig. 2e*).

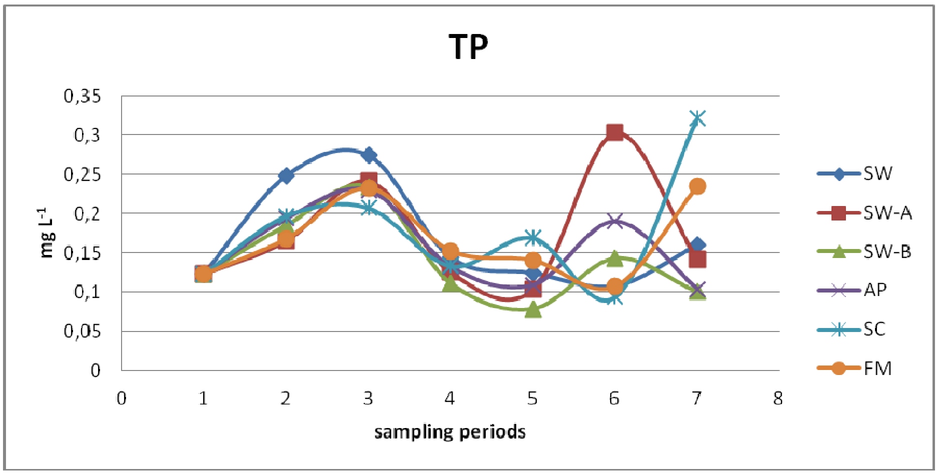

Figure 2e.
The concentration of total phosphorus in all treatments during the trial

The changing of values of TP was similar than the values of PO_4-P. The concentrations were higher in treatment SW-A (0.303 mg l^{-1}) at the 6^{th} sampling date and in treatment SC (0.322 mg l^{-1}) and FM (0.235 mg l^{-1}) at the last sampling date. The values of total suspended solids (TSS) were changeful during the experiment (*Fig. 2f*).

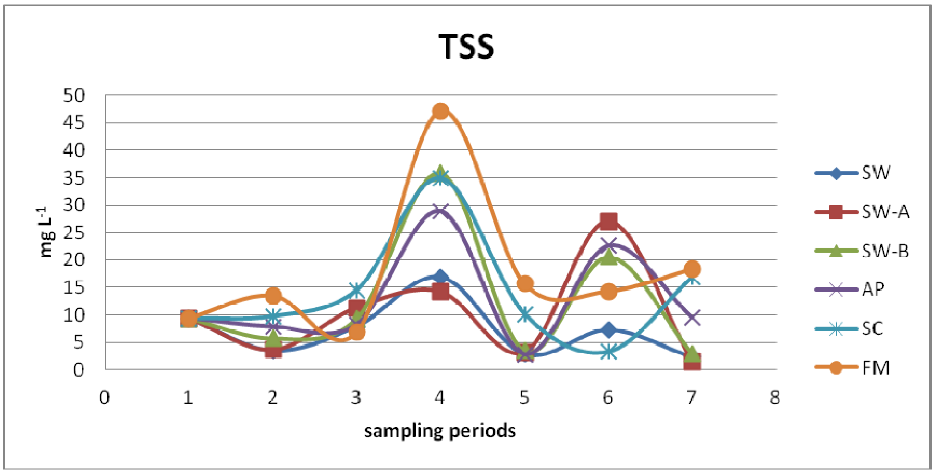

Figure 2f.
The concentration of total suspended solids in all treatments during the trial

Double concentrations were observed during the study, in treatment FM (47.2 mg l^{-1}), SC (34.87 mg l^{-1}), AP (28.93 mg l^{-1}) and SW-B (35.87 mg l^{-1}) at the 4^{th} sampling date; SW-A (27.07 mg l^{-1}), SW-B (20.52 mg l^{-1}) and AP (22.62 mg l^{-1}) at the 6^{th} sampling date. We found significant difference ($p<0.05$) between the treatments in the last sampling date.

The water quality parameters (mean±SD, maximum, minimum) are shown in *Table 3*. Total ammonia nitrogen was similar in treatment SW, AP, FM, and SC, SW-A, SW-B too, but the differences were not statistically different. The highest values of NO_3-N were measured at the end of June. The means of NO_3-N were similar in treatment SC, AP, and FM. The minimum values of NO_2-N and TN harmonized with each other. The lowest values were found in the refill water. The highest average value of TN was in treatment FM and SC. The average total suspended solid was the higher in treatment FM. The biggest difference was found between the treatment FM and SC, but it was not statistically significant. The concentration of Chlorophyll-a was the highest in treatment FM and SC. The concentration was below the measuring range in treatment SW and SW-B at the last sampling date.

Table 3.

Water quality parameters (mean±SD, maximum, minimum)

	SC	SW	SW-A	SW-B	AP	FM
TAN (mg L^{-1})	0.17±0.06	0.22±.01	0.15±0.09	0.17±0.14	0.21±0.11	0.23±0.17
max	0.29	0.47	0.38	0.66	0.57	0.76
min	0.09	0.11	0.03	0.02	0.05	0.1
NO_3-N (mg L^{-1})	0.04±0.04	0.06±0.06	0.05±0.04	0.07±0.12	0.04±0.03	0.04±0.03
max	0.15	0.26	0.15	0.5	0.11	0.12
min	0.01	0.01	0.01	0.004	0.002	0.001
NO_2-N (mg L^{-1})	0.03±0.02	0.05±0.04	0.02±0.01	0.03±0.02	0.03±0.02	0.02±0.02
max	0.07	0.15	0.06	0.085	0.09	0.07
min	0.01	0.01	0.01	0.01	0.01	0.01
TN (mg L^{-1})	0.98±0.7	0.88±0.63	0.82±0.51	0.81±0.47	0.85±0.52	1.02±0.74
max	2.51	2.79	1.76	1.7	2.07	3.16
min	0.16	0.16	0.16	0.16	0.16	0.16
PO_4-P (mg L^{-1})	0.07±0.03	0.08±0.05	0.08±0.04	0.06±0.03	0.07±0.04	0.06±0.03
max	0.13	0.17	0.15	0.12	0.14	0.12
min	0.02	0.02	0.03	0.02	0.03	0.02
TP (mg L^{-1})	0.18±0.08	0.17±0.08	0.18±0.08	0.14±0.06	0.16±0.06	0.17±0.07
max	0.37	0.33	0.4	0.26	0.26	0.39
min	0.06	0.06	0.06	0.05	0.05	0.04
TSS (mg L^{-1})	14.62±10.99	6.92±7.97	10.1±9.55	12.76±15.42	13.12±11.48	18.79±16.14
max	47.2	35.4	33.6	52	36.8	65
min	0.1	0.2	0.1	0.2	0.2	3.1
Chl-a (mg L^{-1})	41.18±57.86	13.14±17.78	26.22±51.62	18.84±23.89	15.26±23.02	42.82±50.61
max	189	78.7	210	84.6	81.8	195
min	5.92	<1	1.06	<1	2.54	2.54

Sediment

The results of analysis of sediment are shown in *Table 4.* Dry matter content in the sediment increased in all treatments at the end of the experiment. This increase was the lowest in treatment SW-A (1.57 m/m %) and AP (1.64 m/m %) and the highest in treatment SC (10 m/m %) and SW (12.53 m/m %). In the treatment SW-B and FM, the increase was 5.4 m/m % and 6.24 m/m %. There were no significant differences among the treatments at the end of the experiment, although we found at the start of the experiment. The content of Kjeldahl-N (KN) increased in the sediment in treatment SC (46.67 mg l^{-1}) and SW (155 mg l^{-1}). The content of KN decreased in another four treatment (SW-A: 95.11 mg l^{-1}; SW-B: 220.33 mg l^{-1}; AP: 107.66 mg l^{-1}; FM: 33.33 mg l^{-1}). The highest value of KN was in treatment FM (1456.67 mg l^{-1}), it was significantly higher ($p<0.5$) than the value of treatment AP and SW-A. The value of KN in treatment SC (1346.67 mg l^{-1}) was significantly higher ($p<0.5$) than the value of treatment AP and SW-A too. The difference between treatment SW and SW-A was significant ($p<0.5$) too. The content of P decreased in dry matter in all treatment. We found significant difference ($p<0.5$) in the content of P of sediment between the treatment at the start of the experiment. We did not find significant difference between the treatments at the end of the experiment. The decrease was the lowest in treatment SW, 62.7 %. The highest decreases were in treatments SC and FM, 78.1 %. The values of manganese increased during the experiment. The lowest values were in treatment SC and AP. These were significantly lower ($p<0.5$) than the values of another treatment. The highest increase was in treatment SC and

AP. The values of the end of the experiment were seven times higher than the start of the experiment. These values were four times higher in another treatment. In content of Mn was significantly different ($p<0.5$) between the treatments.

Table 4.
Mean±SD of dry matter, Kjeldahl-N and phosphorus at the start (S) and end (E) of the experiment

		Dry matter	Kjeldahl N	P	Mn
		m/m%	mg/L	mg/kg d.m.	mg/kg d.m.
SC	S	47.57±1.62	1300±34.64	2643.33±102.14	903.33±11.55
	E	57.57±2.97	1346.67±281.48	579.67±41.06	6723.33±551.94
SW	S	54.8±3.57	1138.33±211.68	2006.67±222.79	1246.67±58.59
	E	67.33±2.32	1293.33±135.03	748±135.5	5766.67±524.33
SW-A	S	63.03±6.03	920.33±324.71	1880±196.98	1413.33±271.35
	E	64.6±4.61	825±222.79	499.33±125.62	6550±1135.83
SW-B	S	51.07±3.46	1320±255.34	2303.33±250.07	1513.33±110.6
	E	56.47±7.35	1099.67±416.25	539±58.62	6850±858.1
AP	S	55.03±1.16	1021.33±84.29	2060±87.18	933.33±11.55
	E	56.67±3.3	913.67±83.44	517±72.67	6750±502.1
FM	S	46.43±2.37	1490±230.65	2776.67±263.88	1413.33±56.86
	E	52.67±4.36	1456.67±225.02	608.67±81	5943.33±397.03

DISCUSSION

European catfish groups fed FM and AP diets showed good growth and feed utilization in the current study. The performance of catfish fed on plant protein source with fish meal or meat meal was significantly better than that on fish fed on only plant protein source. This study demonstrated that soybean meal with corn and meat meal is an acceptable alternative feed component in a European catfish diet. This is in agreement with the results obtained with several fish species. *Kaushik et al.* (2004) demonstrated that the fish meal and oil can be replaced with soybean meal, corn, and wheat gluten in 74 % in the diet for European seabass (*Discentrarchus labrax*). The growth of African catfish reduced significantly on the diet which included more than 50 % extruded or extracted soy and less than 15 % fish meal (*Hoffman et al.* 1997). Mean weight and SGR of African catfish (*Clarias gariepinus*) fed on diet including 60 % soybean meal, was negatively impacted (*Imorou Toko et al.*, 2008). *Davies and Gouveia* (2008) observed that more than 20 % soybean meal content decreased the growth of African catfish. In their experiment values of FCR and SGR were better than our results at 28 % fishmeal and 31 % pea protein concentrate. *Cho and Lowell* (2002) showed that at constant digestible energy (3.08 kcal g^{-1}) in the diets for channel catfish (*Ictalurus punctatus*) the FCR slightly improved as the dietary protein and soybean meal level increased. Animal protein total replacement with soybean meal (36 or 45 % protein) in channel catfish fry diet did not limited the growth of fish (*Sink et al.*, 2010). *Collins et al.* (2012) reported that the increasing SBM content affected negatively the performance of rainbow trout (*Oncorhynchus mykiss*). *Hernández et al.* (2007) reported that fishmeal replacement with soybean meal at a rate of 40% or more, negatively impacted the growth of small size sharpsnout sea bream (*Diplodus puntazzo*). In the diet of juvenile tin foil barb soybean meal may be included up to 37 % as a substitute for fish meal (*Elangovan and Shim* 2000).

Substitution of fish meal with soybean meal plus amino acids or other protein sources in the diet of fishes has also been well documented. *Fagbenro* (1999) reported that the growth of African catfish was reduced at 80 % replacement of fish meal with winged bean meal, but when the winged bean meal was supplemented with methionine there was no significant difference between the treatments. *Essa et al.* (2011) used three different dry yeast levels in African catfish (*Clarias gariepinus*) feeds and reported that the diet supplemented 2 % brewery yeast could improve significantly the FCR, this value was identical with our result obtained in AP treatment. Similar results reported in the experiment with Nile tilapia (*Oreochromis niloticus*) (*M. Abdel-Tawwab et al.*, 2008). Fish meal could totally be replaced with a methionine supplemented soybean meal at protein level settled to 35 % in diet for blue catfish fed until satiation (*Webster et al.*, 1995). *Kikuchi* (1999) reported that 35 % of fish meal can be replaced with soybean meal in combination with blood meal, corn gluten meal and blue mussel meat in the diet of Japanese flounder (*Paralichthys olivaceus*).

It was revealed in our study that high level of soybean meal (50 % in diet SW, SW-A, SW-B) in the diet reduced the growth significantly. This reduction could have been due to higher FCR and lower PER (Table II). Similar results have also been reported in earlier studies with yellowtail (*Seriola quinqueradiata*) (*Vivyakarn et al.*, 1992), sea bream (*Sparus aurata*) (*Kokou et al.*, 2012), rainbow trout (*Pongmaneerat and Watanabe*, 1992), coho salmon (*Oncorhynchus kisutch*) (*Arndt et al.*, 1999), cobia (*Rachycentron canadum*) (*Chou et al.*, 2004) and saddled bream (*Oblada melanura*) (*Antolović et al.*, 2012).

Filipiak et al., (1997) used a commercial trout feed (Aller Mölle 3800-903; 48.5 % crude protein, 14.4 % lipids) to feed European catfish. In their experiment, the values of SGR (3.35 – 1.9) and FCR (0.9 – 1.42) were better than our results at 2 % of feed ratio. *Ulikowski et al.*, (2003) obtained similar results in a 62 days experiment with trout feed (46 % protein, 14 % fat) at 1-1.7 % feed ratio. *Zaikov et al.* (2008) reported mean SGR values of 0.99 and 1.12 % day^{-1} for Wels fed on one-year-old common carp.

Water quality management is of great importance in aquaculture in these days. It is strongly influenced by stocking density, fish species, feeding methods (quality and quantity of nutrients) and the systems to be used. The water temperature (23.23±3.27 ^{o}C) was within the suitable range for European catfish. In the 80s other authors reported aboz this species' thermal optimum (*Müller and Váradi*, 1980, *Hilge*, 1985, *Jungwirth*, 1986).

Concentrations of nitrogen forms and chlorophyll-a increased and the concentration of DO decreased in all treatments. Similar results found in channel catfish ponds *Cole and Boyd* (1986), *Tucker et al.*, (1979) and *Hollerman and Boyd* (1980). *Farrelly et al.*, (2015) observed similar results in intensively aerated pond system. Nitrite-nitrogen concentrations averaged below 0.03 mg L^{-1} until the end of August. The accumulation of nitrite apparently resulted in denitrification in the sediment. *Lovell* (1979) has been reported methemoglobinemia in channel catfish by elevated nitrite concentrations. In this study, the condition was not observed. The increasing concentration of TAN probably resulted from greater feeding rates and from disturbance of sediments by mixing near the end of the experiment. *McGee and Boyd* (1983) observed similar result in the case of TAN in their experiment.

According to the results processed animal protein is a suitable alternative instead of fish meal. Enzymatic supplementations have not been as useful as expected. Its reason needs further investigation. Meat meal has not changed the water quality parameters compared to other treatments.

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