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Original Article

Effect of Partial or Total Replacement Fish meal By Canola Protein Concentrate on Growth performance and Feed Utilization of Juvenile *Oreochromis niloticus*

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Abstract

An experiment was conducted to investigate the effect of replacing fish meal by 25, 50, 75and 100% canola protein concentrate meal (CPC) on growth performance, feed utilization, apparent nutrient digestibility and body composition of juvenile *Oreochromis niloticus*. Experimental diets were prepared to be isonitrogenous and isocaloric (34% CP; 19.4 kJ GE/ g DM). Three hundred fish (mean weight 43.6 ± 0.06 g) were cultured in plastic tank containing fresh water (28°C average temperature) for a period of 56 days. At the end of the experimental period, no significant differences were observed for weight gain (WG) and specific growth rate (SGR) among juvenile tilapia fed on control diet and diets containing CPC at level of 25%, 50% and 75%, respectively. Diet containing 100% CPC showed lower (WG) and (SGR). The data of feed utilization in terms of feed conversion ratio (FCR) showed the same trend of (SGR). However, protein efficiency ratio (PER) and protein retention efficiency (PRE) showed no differences among the fish groups fed on tested diets. No differences were found between control diet and diet containing 25% CPC in terms of apparent protein digestibility (APD). While, APD decreased with the fish groups fed diets containing 50, 75 and 100% CPC levels. However, Phosphors digestibility decreased staidly with increasing CPC levels. No significant differences ($P<0.05$) in whole fish body composition. Slightly decrease in whole body ash content was detected. The results of this study show that juvenile *Oreochromis niloticus* can be cultured with feeding a diet containing 75% canola protein concentrate as fish meal replacer without any adverse effects on growth performance, feed utilization and body composition.

Key words: *Canola protein concentrate, growth, feed utilization, Oreochromis niloticus.*

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Introduction

The global aquaculture production of tilapia has drastically increased from 124 thousand mt (metric tons) in 1997 to 2.5 million mt in 2010 (FAO 2010). This trend suggests that there will be even greater increases in the future. Among the cichlid species, it is the Nile tilapia (*Oreochromis niloticus*) that has dominated global tilapia culture. The tilapia market has expanded from a subsistence level to meet the protein needs of the middle class because of the year-round supply, delicious flavor and reasonable price of that fish. To maintain the tilapia as a global staple protein source during a period of limitations in the world supply of energy, a reduction in the production costs of tilapia is necessary. Traditionally, fish meal (FM) has provided a major part of the protein source of formulated diets because of its suitability as protein quality. Since the recent scarcity and uncertain consistency of supply of FM, its replacement by alternative protein sources that are of high quality, but less expensive, has been investigated. The limitations on the world's food supply provide additional motivation (Naylor et al. 2000; New and Wijkström, 2002) to find fish meal replacers. Therefore, numerous studies have been undertaken to examine the effects of replacing FM by other protein sources such as plant proteins or animal by-products to be used in tilapia diets (Richter *et al*., 2003; Cavalheiro et al. 2007; Nguyen and Davis 2009; Vechklnag et al. 2011). Canola protein concentrate (CPC) / rapeseed ranks second behind soybean meal in the global production of protein from oil cakes and meal. Canola is the name given to selected varieties of rapeseed that are low (in what?). In 2009, 61.6 Mt of rapeseed/canola (*Brassica napus L*., *B. campestris L*.) were produced as sources of vegetable oil worldwide (FAO 2010). Thus, following oil extraction, enormous amounts of oilcake become available. Canola meal is widely used in livestock feed systems and canola concentrates have been developed to be used in animal feeds. Recently, canola concentrate have been developed for the food industry with the first producer approaching commercial release. Although the amino acid profile of canola is suitable for fish nutrition (Higgs et al. 1996), the oilcake or processed products that were de-oiled with organic solvents retain a variety of anti-nutritional factors (ANFs) namely glucosinolates, phytic acid, phenolic constituents and indigestible carbohydrates (Mawson et al. 1995; Francis et al. 2001). These anti-nutritional factors potentially limit the suitability of simple canola products (meals and concentrates) as a protein source and fish meal alternative in finfish diets at relatively high inclusion levels as shown in experiments with *Oncorhynchus mykiss* (Burel et al. 2000a &c, 2001; Thiessen et al. 2003, 2004; Shafaeipour et al. 2008), *Oreochromis mossambicus* (Davies et al. 1990), *Ictalurus punctatus* (Webster et al. 1997), *Cyprinus carpio* (Dabrowski and Kozlowska 1981), *Pagrus auratus (*Glencross et al. 2004) and *Psetta maxima* (Burel et al. 2000a,b). Although several processing techniques such as dehulling of seeds, heat and water treatments, utilization of organic solvents and ultrafiltration will increase protein levels and reduce levels of antinutrients in canola products (Fenwick et al. 1986; Anderson-Hafermann et al. 1993; Tripathi et al. 2000; Tyagi 2002; Chabanon et al. 2007) the benefits for fish nutrition are variable. In previous work, a canola protein concentrate with a crude protein content of 710g kg^{-1} and extremely low levels of glucosinolates was tested as fish meal replacement in diets for *Cyprinus carpio* and *Silurus glanis* (Slawski et al. 2011a,b). In addition, the replacement of fish meal with rapeseed protein concentrate at levels above 33% in carp and 25% in catfish affected negatively on diet palatability and feed intake leading to reduced feed efficiencies. The aim of the present study was to evaluate the potential of a canola protein concentrate (C.P.806g kg^{1}) as fish meal alternative in the nutrition of Nile tilapia juvenile.

Material and methods

Experimental conditions

The experiment carried out at the experimental farm (fish water lab) of the Department of Animal Sciences (DNTW) – Division of Animal Nutrition Physiology, Georg-August-University, Goettingen, Germany. The tested diets were applied in a semi-closed in-door water recirculation system with 15 circular plastic tanks (380-L/tank). Each tank was continuously supplied with a mixture of fresh water and biologically filtered fresh water. Water temperature was kept at (28 ±0.8 ºC) and Photoperiod were regulated as (12h light: 12h dark. The others water quality parameters including pH, ammonia, $N0_2$ and $N0_3$ were recorded weekly and found to be within the acceptable ranges reported by Plumb (1999).

Experimental fish

All male juvenile Nile Tilapia *Oreochromis niloticus*, originating from the lake Manzala (Egypt) population were obtained from department of Animal science, Division of Animal Breeding and Animal Genetics of Georg August University, Goettingen, Germany. Fish were acclimatized to laboratory conditions for two weeks and being distributed into plastic tanks of 380-L water capacity each. Three hundred fish with an average of 43.7 ± 0.06 g initial body weight were stocked in 15 circular experimental plastic tanks (20 fish per tank), totally three replicates nutritional group for each experimental diet were used. All fish in each tank were weighed every 14 days. During the growth period, each diet was offered to fish groups by hand 4 meals/day until apparent satiation.

Experimental diets

Five iso-nitrogenous and iso-caloric diets were formulated from practical ingredients (fish meal, canola protein concentrate soybean meal wheat and corn) to contain almost 34% crude protein 19.4 MJ GE/ g DM feed (Tables 1 & 2). One basal diet as control diet and other 4 diets supplemented with 25, 50, 75 and 100% canola protein concentrate were used to replace fish meal protein, respectively. Crystalline amino acid (DL-.Methionine) was added to all diets to cover the amino acid requirements of tilapia according to (NRC 2011) Table 2. Fish oil was added as a major dietary lipid source to make all diets isolipidic. The vitamin mixture was added to all experimental diets at a constant level of 1%. As an indigestible marker 0.3% TiO_2/kg feed was in corrupted. The wet mixtures were pelleted by granule machine (Co. Lister, England) to 2.2 mm granules and dried in a ventilated oven at 40^{o}C for 24 hours. The dried pellets were stored in a cool room at 2ºC.

Table 1. Nutreint composition (g kg $^{-1}$ DM), essential amino acid profile of Fish meal and canola protein concentrate.

Item	Fish meal	Canola protein concentrate
Dry matter (g kg -1)	910	947
Crude protein	640	806
Essential Amino acid		
Arginine	33.8	27.6
Histidine	18.2	16.4
Leucine	43.7	54.3
IsoLeucine	24.9	27.5
Lysine	46.6	39.9
Methionine+ Cysteine	20.9	32.1
Phenylalanine+Tyrosine	49.6	64.2
Thrionine	24.9	35.9
Valine	28.6	30.1

Digestibility study

The apparent nutrient digestibility was performed in six sedimentation systems (0.15 m^3 per system) with an aeration equipment, water temperature control and continuous water exchange according to Fassbender (1990) and Mielke (1992). Triplicate groups each include 10 tilapia with an initial body weight of 150 g were fed two daily meals up to apparent satiation.

Faces collection was conducted 4 h after each feeding using an external sedimentation column. Faces were immediately stored in freezer (−20 °C). Based on simplicity of its application and the precision of the analytical methods associated with its use; TiO_2 was incorporated as inert indicator (Vanderberg and De La Noüe, 2001; Portz & Liebert 2004). Apparent digestibility coefficients (ADC, %) were calculated according to De Silva and Anderson (1995), as follows: ADC = [1-(TiO2 diet/ TiO2 faces x Nutrient faces / Nutrient diet)].

Table 2. Diet formulation and Nutrient composition of the experimental diets ($g \cdot kg^{-1}$ DM)

Ingredients	Experimental Diets				
	Control (1)	(2)	(3)	(4)	(5)
Fish meal	200	150	100	50	0
Canola Protein Concentrate	0	41	82	123	164
Soybean meal	300	300	300	300	300
Wheat	150	150	150	150	150
Corn	250	250	250	250	250
Fish oil/Soybean oil[1]	40	44	49	53	57
Premix [2]	15	15	15	15	15
MCP 3	10	10	10	10	10
Ti02	3	3	3	3	3
CMC4	20	20	20	20	20
DL-Met	2,22	2,4	2,58	2,65	2,84
Wheat starch	9,78	14,6	18,42	23,35	28,16
Total	1000	1000	1000	1000	1000
Nutrient content of the experimental diets (g/kg DM)					
Crude protein	339	340	337	337	330
Crude lipids	82.8	85.3	92.9	94.1	97.0
Crude ash	86.0	80.6	72.2	63.9	57.9
Crude fibre	34.7	36.7	35.7	36.6	36.8
N-free extract	458.1	457.4	462.2	468.4	478.3
Phosphours	9.7	9.2	8.3	7.0	6.0
Gross energy (kJ g-1) 1	19.1	19.3	19.6	19.7	19.8
P:E (g MJ-1)	17.7	17.6	17.2	17.1	16.7

1- constant ratio (1:1)
2- Contains per kg: $MnSO_4$, 40 mg; MgO, 10 mg; K_2SO_4, 40 mg; $ZnCO_3$, 60 mg; KJ, 0.4 mg; $CuSO_4$, 12 mg; ferric citrate, 250 mg; Na_2SeO_3, 0.24 mg; Co, 0.2 mg; vitamin A, 4000 IU; vitamin B6, 30 mg; vitamin D3, 400 IU; vitamin E, 400 mg; vitamin B12, 80 µg; vitamin B1, 30 mg; vitamin B2, 40 mg; vitamin K3, 12 mg; folic acid, 10 mg; biotin, 3 mg; pantothenic acid, 100 mg; inositol, 50 mg; ascorbic acid, 500 mg.
3- MCP: Mono Calcium Phosphate
4- CMC: Carboxy methyl cellulose
5- Gross energy. Based on 5.65 kcal/g protein, 9.45 kcal/g fat and 4.1 carbohydrate kcal/g (NRC, 2011)

Sample collection and chemical analysis

At the beginning of the experiment, ten fish were analyzes for body composition. Three fish/ tank were sampled at the end of the experiment, killed by anesthetic over dose (Ethylene-glycol-monophenyl-ether), autoclaved (110 ºC, 3 h), homogenized with lab mixer and stored at -20 ºC for subsequent chemical analysis. Chemical analyses of ingredients, diets and homogenized fish were conducted according to German standard methods (Naumann and Bassler 1976-1997) in duplicates. For dry matter determination an electric oven at

110^{o}C (Memmert) was used until constant weight; crude ash was detected by 4 h ashing at 600^{o}C in a furnace muffle (Thermicon P; Heraeus Holding). A nitrogen auto-analyzer (FP-2000; Leco) was utilized for crude protein determination using the Dumas-method (N×6.25). Ether extract was determined by extraction with petroleum ether according to the Soxhlet-procedure following HCl-hydrolysis of the feed samples. Gross energy of the diets was calculated according to NRC (2011), based on crude nutrient analyses. Phosphours ditermenation by using spectrophotometer (Specord S100). Amino acids analyses (except tryptophan) were conducted by ion-exchange chromatography (LC 3000, Biotronic, Eppendorf-Netheler-Hinz GmbH, Hamburg, Germany) following acid hydrolysis with and without an oxidation step for determination of sulphur-containing amino acids.

Parameters of feed efficiency and growth study

Calculation of parameters feed conversion ratio FCR (g feed/g gain), specific growth rate SGR (%/ d), feed intake FI (%), protein efficiency ratio PER (g protein/g gain), and protein deposition PD (%) was according to Takeuchi (1988) and Tacon (1990).

Statistical analysis

All data of growth performance and feed utilization were analyzed by one-way analysis of variance (ANOVA) using the general linear models procedure of statistical analysis system (SPSS) version 17, (2009). Differences between means were assessed by Duncan's multiple range test (Duncan, 1955) and effects with a probability of $P < 0.05$ were considered significant.

Results

The survival rate of juvenile Nile tilapia after eight weeks of feeding the experimental diets was 100%. All the water quality parameters were within the acceptable range for Nile tilapia where, dissolved oxygen, 6.50 ±0.27 mg/L; water temperature, 27.8 ±.4^{o}C; ammonia, 0.080 ±0.052 mg/L; nitrite-N, 0.038 ± 0.023 mg/L; and pH, 7.8 ± 0.2. These values were within optimum ranges for normal growth and health of juvenile Nile tilapia Plumb (1999). Average of initial body weight of Nile tilapia fingerlings fed the experimental diets at the start did not differ significantly ($P>0.05$), indicating that fish groups were homogenous. The growth performance of juvenile Nile tilapia fed on the experimental diets is shown in Table 3. At the end of the experiment, the weight gain of all male tilapia-fed tested diets showed no statistical differences among groups ($P>0.05$) except for diet 4 containing 100% CPC which records the lowest weight gain (143.6g) (Table 3). Specific growth rate (SGR) showed also the same trend reported by weight gain (Table 3). The statistical data of feed intake showed no significant effect ($P>0.05$) when fishmeal was totally replaced by CPC. This result suggests that the palatability of the tested diets is not reduced when CPC completely replaces fishmeal. The statistical analysis of feed utilization in terms of feed conversion ratio (FCR) showed no significant effects by increasing levels of fish meal substations in groups of fish fed the experimental diets up to diet 3 , where 75% of the fish meal protein was re[placed by CPC (Table 4). Means of feed conversion ratio (FCR) were found to be 1.32, 1.32, 1.34, 1.37 and 1.43, for diets 1,2,3,4, and 5, respectively. Additionally, the results indicated that the highest level of feed utilization was recorded for control diet (100% FM) followed by diet 1 which contain (75%FM: 25%CPC). However, protein efficiency ratio (PER) showed no significant effects ($P>0.05$) by increasing levels of fish meal substations in groups of fish fed the experimental diets (Table 4). This suggests that the inclusion high level of CPC does not impair the ability of tilapia to digest and absorb protein and energy from the diet. This effects were reflected by the observed of protein efficiency ratio (PER) which was found to be 2.35, 2.35, 2.34, 2.29 and 2.27, respectively. However, the results of protein retention efficiency (PRE)

reported that the highest level of (PRE) by diet 2 (25%FM: 75%CPC) followed by control diet and diet 5. The results of protein and phosphorus digestibility are presented in table 5. The digestibility data showed that decreasing of protein and phosphorus digestibility by increasing level of CPC. The statistical analysis of protein digestibility showed no significant differences (P>0.05) between control diet 1(85.2%) and diet 2 (82.9%) and significantly reduced by diet 3 (75.6%), diet 4 (75.4%) followed by diet 5 (75.3%). The statistical data of phosphors digestibility showed high significant (P<0.05) by control diet 1(39.7%) as compared with the rest groups and decreased gradually by increasing level of CPC in the tested diets. The results of body composition are presented in table 6, where no significant effect was observed of experimental diets on Tilapia body composition at the end of the study. The results of fish group fed diet contain 100% CPC were significantly (P<0.05) lower in whole ash content than the rest groups.

Discussion

As a typical omnivorous fish species, farmed tilapia mainly depends on vegetable protein sources in commercial feed manufacturing; except in diets for fingerlings phase. Several reports conducted by using plant protein on fingerlings or juvenile for growth of tilapia with different conclusions (El-Saidy and Gaber 2003; Furuya et al. 2004; Goda et al. 2007; Vechklnag et al. 2011). Rapeseed protein concentrate and Canola protein concentrate has been found to be a viable alternative to fish meal in fish feeds. Different

Table 3. Summarized growth data of Tilapia (*O. niloticus*) fed on the experimental diets

		Growth Data		
Diet No	InitialBW(g/fish)	FinalBW(g/fish)	BW gain(%)1	SGR (%/d)2
1 (100% FM)	43.6	154.6±2.8a	254.5±6.5a	2.26±0.03a
2 (75% FM:25 % CPC)	43.6	154.2±1.8[a]	253.2±4.4[a]	2.25±0.02[a]
3 (50% FM:50 % CPC)	43.7	152.7±1.1[a]	249.6±3.3[a]	2.24±0.01[a]
4 (25% FM:75 % CPC)	43.7	148.9±1.5[ab]	241.8±3.3[ab]	2.19±0.01[ab]
5 (100% CPC)	43.7	143.6±3.5[b]	228.6±8.4[b]	2.12±0.04[b]

Value in the same column with different superscript letters are significantly different (P<0.05).

[1)] Weight gain (%) = 100 (final BW - initial BW): initial BW

[2)] Specific growth rate (SGR, $\%d^{-1}$) = 100 (ln final BW - ln initial BW): days of experiment)

Table 4. Feed and protein efficiency parameters of (*O. niloticus*) fed on experimental diets

		Feed Utilization		
Diet No.	Feed intake(g/g)	FCR1 (g/g)	PER2(g/g)	PRE3 (g/g)
Control (1)	146.5	1.32±0.01a	2.35±0.03a	38.6±0.46a
Diet (2)	146.0	1.32±0.01a	2.35±0.03a	38.9±0.52a
Diet (3)	146.1	1.34±0.01a	2.34±0.01a	36.9±0.17a
Diet (4)	144.1	1.37±0.01ab	2.29±0.03a	36.4±0.48ab
Diet (5)	143.0	1.43±0.04[b]	2.27±0.07[a]	37.2±1.2[a]

Value in the same column with different superscript letters are significantly different (P<0.05).

[1)] Feed conversion ratio (g/g) = Feed consumed: BW gain

[2)] Protein efficiency ratio = fish wet weight gain/protein intake.

[3)] Protein retention efficiency=100× (final body protein – initial body protein)/total protein fed.

Table 5. Apparent phosphor and protein digestibility of (*O .niloticus*) fed on experimental diets

Experimental groups	Phosphor%	Protein%
Control (1)	39.7 a	85.2 a
Diet (2)	31.8 [b]	82.8 [a]
Diet (3)	27.4 [b]	75.6 [b]
Diet (4)	23.5 c	75.4 [b]
Diet (5)	17.4 d	75.3 [b]

Value in the same column with different superscript letters are significantly different (P<0.05).

Table 6. Proximate whole body composition of (*O. niloticus*) fed on experimental diets

Experimental groups	Whole body composition (g/kgDM)			
	Dry matter	Crude protein	Crude lipids	Ash
Initial	200.9	661.1	131.3	207.6
Control (1)	271.4±1.13a	574.1±1.9a	259.6±2.08a	166.3±0.28a
Diet (2)	268.3±0.93a	583.2±1.5 a	251.5±1.96a	165.3±0.44a
Diet (3)	283.6±0.32a	546.3±0.75a	284.6±0.76a	169.1±0.98a
Diet (4)	256.7±0.81a	590.1±1.14a	256.2±2.13a	153.7±0.26b
Diet (5)	261.7±0.92a	577.4±2.07a	292.0±1.85a	133.7±0.23c

Means within the same column with different superscript letters are significantly different (P<0.05).

Replacement levels of fish meal have been achieved by inclusion of rapeseed and canola protein concentrate in feeding trials with several fish species (Dabrowski and Kozlowska 1981; Lim et al. 1998; Burel et al. 2000 a,b,c; Booth and Allan 2003; Glencross et al. 2004; Thiessen et al. 2004; Yigit and Olmez 2009). It was found, that antinutritional factors presented in canola particularly determine its value as fish nutrient. It was therefore recommended to reduce antinutritional factors in canola protein concentrates in order to achieve higher fish meal replacement levels in fish diets. In the present study canola protein concentrate (CPC) with 80 % crude protein content and particularly low levels of glucosinolates, phytic acid and tannins was tested as fish meal alternative in diets for Nile Tilapia. The CPC successfully replaced 75 % of fish meal protein from the control diet without retarding fish growth performance. In contrast to our investigation, (Slawski et al. 2011a,b).reported that , consequently fish growth decreased when catfish or carp received diets with more than 25 % or 33 % of fish meal replaced by rapeseed protein concentrate. This was referred to dietary levels of NFE and insufficient phosphorus availability or probably due to glucosinolates present in rapeseed. While, Dabrowski and Kozlowska (1981) successfully replaced 100% of fish meal protein from diets for common carp with rapeseed meal protein without reducing fish weight gain or standard growth rate. In agreement with our investigation, Slawski et al. (2013) reported that rainbow trout can be fed on diet replaced 100% fish meal protein by canola protein isolate (CPI) without any adverse effects on weight gain or specific growth rate. In the present study, results of feed efficiency in terms of feed conversion ratio (FCR), protein efficiency ratio (PER) and protein retention efficiency (PRE) are illustrated in Table (4). It was found no significant differences (P<0.05) among

experimental groups. The highest value of feed and protein intake was recorded in group of fish fed control diet and diet 2 followed by diets 3, 4 and diet 5, respectively. This indicates that the taste of canola protein concentrate was well accepted by tilapia, the best value of feed conversion ratio was recorded for control diet 1 and diet2 (1.32) while the lowest feed conversion ratio value was recorded for diet 5 (1.43) followed by diet 4 (1.37) and diet 3 (1.34), respectively. The same trend was observed in PER and PRE. These results are in agreements with Slawski et al. (2013) who reported that rainbow trout can be fed on diet replaced 100% fish meal protein by canola protein isolate without no influence on feed efficiency. In several studies, the ADCs of canola protein products in fish diets have been determined. In experiments with Atlantic salmon ADC of the protein from canola meal was found to be 74.0% (Anderson et al. 1992). However, the canola meal tested had a protein content of 390 g kg^{-1} and therefore contained significant amounts of NFE. Mwachireya et al. (1999) evaluated the protein digestibility of a canola protein isolate in rainbow trout diets, using a settling column for the collection of fish faeces, they found that canola protein isolate ADC is about 97.6 %. This value was regarded as one of the highest ever reported in fish nutrition studies. The authors ascribed this high protein digestibility to the high level of protein (908 g kg^{-1}) and low levels of all antinutritional factors and indigestible carbohydrates present in the canola protein isolate compared to canola concentrates. The CPC used in our study contained 806 g kg-1 of crude protein and 69 g kg-1 of NFE. It appears, that NFE negatively affected protein digestibility of our CPC. However, the apparent protein digestibility showed no significant differences ($P>0.05$) between control diet 1(85.2%) and diet 2 (82.9%) and significantly reduced by diet 5 (75.3%). This result is in agreement with Mwachireya et al. (1999) who observed ADCs for protein between 77.4 to 88.1 % for differently processed canola meals. The phosphorus digestibility in our investigation showed high significant ($P<0.05$) by control diet 1(39.7%) as compared with the rest groups and decreased gradually by increasing level of CPC in the tested diets up to 100% which recorded low level of phosphors digestibility (17.4%). This result may be due to the factors such as phytic acid, fiber and other complex carbohydrates present in CPC which may contributed to reduce phosphorus availability in fish feeds (Francis et al. 2001). It is well known that whole-body ash is reduced when fish are fed a diet deficient in available phosphorus (Skonberg et al. 1997; Shao et al. 2008) and that whole body lipid content can be increased due to high dietary levels of vegetable protein (Adelizi et al. 1998; Kaushik et al. 2004). In the present study, neither differences in whole body composition nor correlations between dietary phosphorus content and ash levels in fish body indicating insufficient dietary phosphorus supply were detected. It has been reported, however, that increased dietary phosphorus levels can improve feed efficiencies and consequently growth in Atlantic salmon, cod and sea bass (Vielma and Lall 1998; Roy and Lall 2003; Oliva-Teles and Pimentel-Rodrigues 2004). Accordingly, the higher phosphorus level in control diet 1 compared to diet 5 may have resulted better feed efficiencies and fish growth. Besides different dietary phosphorus supply, varying dietary levels of NFE might also have contributed to slight differences in growth performances and feed efficiencies among treatment groups. Since dietary NFE can potentially reduce nutrient and mineral digestibility in fish (Storebakken et al. 1998; Burel et al. 2000a; Mwachireya et al. 1999; Francis et al. 2001) lower dietary levels of NFE in diet 1 (458.1 g kg-1) compared to diet 5 (478.3 g kg-1) might have resulted in slightly better growth performance and feed efficiencies.

Conclusion

In conclusion, the canola protein concentrate tested has shown great potential as fish meal replacement in diets for Tilapia

feeding. High dry matter, protein digestibility and low level of antinutritional factors together with accepted palatability make canola protein concentrate a promising candidate as protein source in fish diets.

References

Adelizi, P.D.; Rosati, R.R.; Warner, K.; Wu, Y.V.; Muench, T.R.; White, M.R. and Brown, P.B. 1998. Evaluation of fish-meal free diets for rainbow trout, *Oncorhynchus mykiss*. Aquaculture Nutrition 4, 255–262.

Anderson, J.S.; Lall, S.P.; Anderson, D.M. and Chandrasoma, J. 1992. Apparent and true availability of amino acids from common feed ingredients for Atlantic salmon (*Salmo salar*) reared in sea water. Aquaculture, 108, 111–124.

Booth, M.A. and Allan, G.L. 2003. Utilization of digestible nitrogen and energy from four agricultural ingredients by juvenile silver perch *Bidyanus bidyanus*. Aquaculture Nutrition 9, 317-326.

Burel, C., Boujard, T., Escaffre, A.M., Kaushik, S.J., Boeuf, G., Mol, K., Van Der Geyten, S., Kühn, E.R., 2000c. Dietary low glucosinolate rapeseed meal affects thyroid status and nutrient utilization in rainbow trout (*Oncorhynchus mykiss*). British Journal of Nutrition83, 653–664.

Burel, C.; Boujard, T.; Escaffre, A.M.; Kaushik, S.J.; Boeuf, G.; Mol, K.; van der Geyten, S. and Kühn, E.R. 2000b. Dietary low glucosinolate rapeseed meal affects thyroid status and nutrient utilization in rainbow trout (*Oncorhynchus mykiss*). British Journal of Nutrition 83, 653–664.

Burel, C.; Boujard, T.; Kaushik, S.J.; Boeuf, G.; van der Geyten, S.; Mol, K.A.; Kühn, E.R.; Quinsac A.; Krouti, M. and Ribaillier, D. 2000c. Potential of plant-protein sources as fish meal substitutes in diets for turbot (Psetta maxima): growth, nutrient utilization and thyroid status. Aquaculture 188, 363-382.

Burel, C.; Boujard, T.; Tulli, F. and Kaushik, S.J. 2000a. Digestibility of extruded peas, extruded lupine, and rapeseed meal in rainbow trout (*Oncorhynchus mykiss*) and turbot (Psetta maxima). Aquaculture 188, 285–298.

Burel, C.; Boujard, T.; Tulli, F.and Kaushik, S.J. 2000b. Digestibility of extruded peas, extruded lupin, and rapeseed meal in rainbow trout (*Oncorhynchus mykiss*) and turbot (Psetta maxima). Aquaculture 188, 285–298.

Cavalheiro, J.M.O.; Souza, E.O. and Bora, P.S. 2007.Utilization of shrimp industry waste in the formulation of tilapia (*Oreochromis niloticus Linnaeus*) feed. Bioresour. Technol., 98, 602–606. Chen, C., Wooster, G.A., Getchell, R.G., Bowser, P.R. and Timmons,

Chabanon, G.; Chevalot, I.; Framboisier, X.; Chenu, S. and Marc, I. 2007. Hydrolysis of rapeseed protein isolates: Kinetics, characterization and functional properties of hydrolysates. Process. Biochem. 42, 1419–1428.

Dabrowski, K. and Kozlowska, H. 1981. Rapeseed meal in the diet of common carp reared in heated waters. I. Growth of fish and utilization of the diet. In: K. Tiews (ed.). Aquaculture in Heated Effluents and Recirculation Systems. Heenemann, Hamburg, pp.263-274.

Davies, S.J.; McConnel, S. and Bateson, R.I. 1990. Potential of rapeseed meal as an alternative protein source in complete diets for tilapia (*Oreochromis mossambicus* Peters). Aquaculture 87, 145-154.

De Silva, S. S. and Anderson, T. A. 1995. Fish nutrition in Aquaculture. Champan and Hall, London.

Duncan D.B. 1955. Multiple range and Mmultiple f test Biometrice 11:1-42.

El-Saidy, D.M.S. and Gaber, M.M.A. 2003. Replacement of fishmeal with a mixture of different plant protein sources in juvenile Nile tilapia, *Oreochromis niloticus* (L.) diets. Aquaculture Resarch, 34, 1119–1127.

FAO, 2010. Food and Agriculture Organization of the United Nations. Fisheries and Aquaculture *Oreochromis niloticus*. Available at: http:// fao.org/fishery/ cultured *Oreochromis_niloticus*/ in: Francis, G., Makkar, H.P.S., Becker, K., 2001. Antinutritional factors present in plant-derivedalternate fish feed ingredients and their effects in fish. Aquaculture 199, 197–227.

Fassbender, U. 1990. Untersuchungen zur Energetischen Futterwertermittelung beim Fisch. Diss.Univ. Gottingen, Germany.

Fenwick, G.R.; Spinks, E.A.; Wilkinson, A.P.; Henry, R.K. and Legoy, M.A. 1986. Effect of processing on the antinutrient content of rapeseed. J. Sci. Food Agr. 37, 735-741.

Francis, G.; Makkar, H.P.S. and Becker, K. 2001. Antinutritional factors present in plant-derived alternate fish feed ingredients and their effects in fish. Aquaculture 199, 197–227.

Francis, G.; Makkar, H.P.S. and Becker, K. 2001. Antinutritional factors present in plant-derived alternate fish feed ingredients and their effects in fish. Aquaculture 199, 197–227.

Furuya, W.M., Pezzato, L.E., Barros, M.M., Pezzato, A.C. and Furuya, V.R.B. (2004) Use of ideal protein concept for precision formulation of amino acid levels in fish-meal-free diets for juvenile Nile tilapia (*Oreochromis niloticus* L.). Aquaculture Resarch, 35, 1110–1116.

Glencross, B.; Hawkins, W. and Curnow, J.2004. Nutritional assessment of Australian canola meals. I. Evaluation of canola oil extraction method and meal processing conditions on the digestible value of canola meals fed to the red seabream (*Pagrus auratus*, Paulin).Aquaculture Research 35, 15-24.

Goda, A.M.A-S., Wafa, M.E., El-Haroun, E.R. and Chowdhury, M.A.K. 2007. Growth performance and feed utilization of Nile tilapia *Oreochromis niloticus* (Linnaeus, 1758) and tilapia galilae *Sarotherodon galilaeus* (Linnaeus, 1758) fingerlings fed plant protein- based diets. Aquaculture Research, 38, 827–837.

Higgs, D.A.; Dosanjh, B.S.; Beames, R.M.; Prendergast, A.F.; Mwachireya, S.A. and Deacon, G. 1996. Nutritive value of rapeseed/canola protein products for salmonids. In: CFIA Proc., May 15-17, 1996, Dartmouth/Halifax (Fischer, N. ed.), pp. 187-196. Canadian Feed Industry Association (CFIA), Ottawa, Canada.

Kaushik, S.J.; Covès, D.; Dutto, G. and Blanc, D. 2004. Almost total replacement of fish meal by plant protein sources in the diet of a marine teleost, the European seabass, *Dicentrarchus labrax*. Aquaculture 230, 391–404.

Lim, C.; Klesius, H. and Higgs, D.A. 1998. Substitution of canola meal for soybean meal in diets for channel catfish Ictalurus punctatus. J. of the World Aquacult. Society 29, 161-168.

Mawson, R., Heaney, R.K., Zdunczyk, Z., Kozlowska, H. (1995). Rapeseed meal - glucosinolates and their antinutritional effects: Part 7. Processing. Die Nahrung 39, 32–41.

Mawson, R.; Heaney, R.K.; Zdunczyk, Z. and Kozlowska, H. 1995. Rapeseed meal - glucosinolates and their antinutritional effects: 7. Processing. Die Nahrung 39, 32–41.

Mawson, R.; Heaney, R.K.; Zdunczyk, Z. and Kozlowska, H. 1995. Rapeseed meal - glucosinolates and their antinutritional effects: Part 7. Processing. Die Nahrung 39, 32–41.

McCurdy, C.M. and March, B.E.1992. Processing of canola meal for incorporation in trout and salmon diets. J. Am. Oil Chem. Soc. 69, 213-220.

Mielke, U. 1992. Untersuchungen zur Minimierung der Stickstoff- und Phosphorausscheidungen bei wachsenden Regenbogenforellen (*Oncorhynchus mykiss*). Diss.Univ. Go¨ ttingen, Germany.

Mwachireya, S.A.; Beames, R.M.; Higgs, D.A. and Dosanjh, B.S. 1999.

Digestibility of canola protein products derived from the physical, enzymatic and chemical processing of commercial canola meal in rainbow trout, *Oncorhynchus mykiss* (Walbaum) held in fresh water. Aquaculture Nutrition 5, 73-82.

Naumann, K. and Bassler, R., 1976-1997. Die chemische Untersuchung von Futtermitteln. Methodenbuch Band III, Verlag J. NEMANN-NEUDAM.

Naylor, R.L.; Goldburg, R.B.; Primavera, J.H.; Kautsky, N.; Beveridge, M.C.M.; Clay, J.; Folke, C.;Lubchenco, J.;Mooney, H. and Troell, M. 2000. Effect of aquaculture on world fish supplies. Nature, 405, 1017–1024.

New, M.B. and Wijkstrom, U.N. 2002. Use of Fishmeal and Fisoil in Aquafeeds: Further Thoughts on the Fishmeal Trap. FAO Fish Circ. No. 975. FAO, Rome, Italy.

Nguyen, T. and Davis, D.A. 2009. Evaluation of alternative protein sources to replace fish meal in practical diets for juvenile tilapia, *Oreochromis* spp. J. World Aquacult. Soc., 40, 113–121.

NRC, 2011. Nutrient requirement of fish. National Academy Press, Washington DC.

Oliva-Teles, A. and Pimentel-Rodrigues, A.M. 2004. Phosphorus requirement of European sea bass (*Dicentrarchus labrax* L.) juveniles. Aquaculture. Research, 35, 636–642.

Olsen, R.E.; Hansen, A.C.; Rosenlund, G.; Hemre, G.I.; Mayhew,R.N.; Siddhuraju, P. and Becker, K. 2003. Evaluation of nutritional quality of moringa (*Moringa oleifera* Lam.) leaves as an alternative protein source for Nile tilapia (*Oreochromis niloticus* L.). Aquaculture, 217, 599–611.

Plumb, J.A. 1999. Health Maintenance and Principal Microbian Diseases of Culture Fishes. Iowa State University Press, Ames, IA, 108-126.

Portz, L. and Libert, F. 2004. Growth, nutrient utilization and parameters of mineral metabolism in Nile tilapia *Oreochromis niloticus* (Linnaeus, 1758) fed plant-based diets with graded levels of microbial phytase. J.Anim. Physiol.a. Anim. Nutr. 88, 311-320.

Roy, P.K. and Lall, S.P. 2003. Dietary phosphorus requirement of juvenile haddock (Melanogrammus aeglefinus L.). Aquaculture, 221, 451–468.

Shafaeipour, A. ; Yavari, V.; Falahatkar, B.; Maremmazi, J.G.H. and Gorjipour, E. 2008. Effects of canola meal on physiological and biochemical parameters in rainbow trout (*Oncorhynchus mykiss*). Aquaculture Nutrition 14, 110–119.

Shao, Q.; Ma, J.; Xu, Z.; Hu, W.; Xu, J.and Xie, S. 2008. Dietary phosphorus requirement of juvenile black seabream, *Sparus macrocephalus*. Aquaculture 277, 92–100.

Skonberg, D.I.; Yogev, L.; Hardy, R.W. and Dong, F.M. 1997. Metabolic response to dietary phosphorus intake in rainbow trout (*Oncorhynchus mykiss*). Aquaculture 157, 11–24.

Slawski, H.; Adem, H.; Tressel, R.P.; Wysujack, K.; Koops, U.; Wuertz, S. and Schulz, C. 2011b. Replacement of fish meal with rapeseed protein concentrate in diets fed to wels catfish (*Silurus glanis* L.). Aquaculture. Nutrition, 17, 605–612.

Slawski, H.; Adem, H.; Tressel, R.P.;Wysujack, K.; Koops, U. and Schulz, C. 2011a. Replacement of fish meal with rapeseed protein concentrate in diets fed to common carp (*Cyprinus carpio* L.). IJA, 63, 605–611.

Slawski, H.; Nagel, F.W.; ysujack, K.; Balke, D.T.; Franz, P. and Schulz, C. 2013. Total fish meal replacement with canola protein isolate in diets fed to rainbow trout (*Oncorhynchus mykiss* W.). Aquaculture Nutration 19; 535–542.

Storebakken, T. ; Shearer, K.D. and Roem, A.J. 1998. Availability of protein, phosphorus and other elements in fishmeal, soy protein concentrate and phytase-treated soy protein concentrate-

based diets to Atlantic salmon, *Salmo salar*. Aquaculture 161, 365–379.

Tacon, A.G.J. 1990. Essential nutrients – Proteins andaminoacids.Standardmethods for the Nutrition of Farmed Fish and Shrimp. pp. 2-20. Argent Laboratories Press, Redmond, Washington.

Takeuchi, T.1988. Fish Nutrition and Mariculture. In: Laboratory Work: Chemical Evaluation of Dietary Nutrients. (Watanabe, T. ed.), 179-233. Department of Aquatic Biosciences, Tokyo University of Fisheries, Tokyo.

Thiessen, D.L.; Campbell, G.L.and Adelizi, P.D. 2003. Digestibility and growth performance of juvenile rainbow trout (*Oncorhynchus mykiss*) fed with pea and canola products. Aquaculture Nutrition 9, 67–75.

Thiessen, D.L.; Maenz, D.D. and Newkirk, R.W. 2004. Replacement of fish meal by canola protein concentrate in diets fed to rainbow trout (*Oncorhynchus mykiss*). Aquaculture Nutrition 10, 379–388.

Thiessen, D.L.;Maenz, D.D.; Newkirk, R.W.; Classen, H.L. and Drew, M.D. 2004. Replacement of fish meal by canola protein concentrate in diets fed to rainbow trout (*Oncorhynchus mykiss*). Aquaculture Nutrition 10, 379–388.

Tripathi, M.K.; Agrawal, I.S. and Sharma, S.D. 2000. Effect of physio-chemical treatments on glucosinolates content of various rapeseed–mustard meals. Indian J. Anim. Nutr. 17,211–216.

Tyagi, A.K. 2002. Influence of water soaking of mustard cake on glucosinolate hydrolysis.Animal Feed Science and Technology 99, 215–219.

Vanderberg, G. W.;De, L.a. and Noü, e.J. 2001.Apparent digestibility comparison in rainbow trout (*Oncorhynchus mykiss*) assessed using three methods of faeces collection and three digestibility markers. Aquac. Nutr. 7, 237.

Vechklang.K; Boonanutananasarn.B; Ponchoovong.S; Pirarat .N and Wanapu.C. 2011. The potential for rice wine residual as an alternative protein source in a practical diet for Nile tilapia (*Oreochromis niloticus*) at the Juvenile stage. Aquaculture Nutrition, 17: 685-694.

Vielma, J. and Lall, S.P. 1998.Phosphorus utilization by Atlantic salmon (*Salmo salar*) reared in freshwater is not influenced by higher dietary calcium intake. Aquaculture, 160, 117–128.

Webster, C.D.; Tiu, L.G.; Tidwell, J.H.and Grizzle, J.M. 1997. Growth and body composition of channel catfish (*Ictalurus punctatus*) fed diets containing various percentages of canola meal. Aquaculture 150, 103-112.

Yigit, N.O. and Olmez, M. 2009. Canola Meal as an Alternative Protein Source in Diets for Fry of Tilapia (*Oreochromis niloticus*). The Israeli Journal of Aquaculture - Bamidgeh, 61(1), 35-41.