REPLACEMENT OF CANOLA MEAL FOR SOYBEAN MEAL IN DIETS OF TILAPIA HYBRID (*OREOCHROMIS NILOTICUS* × *OREOCHROMIS AUREUS*) FINGERLINGS.

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SUMMARY

Two feeding experiments were conducted for 90 days each to evaluate the suitability of canola meal (CM) as a partial or complete substitute for soybean meal (SBM) in diets of tilapia hybrid fingerlings (*Oreochromis niloticus* × *Oreochromis aureus*). All the experimental diets were formulated to be isonitrogenous and isoenergetic to contain 25.4% crude protein and 4514 kcal gross energy/kg. In the first and the second feeding experiments, five diets were formulated to replace SBM with CM at 0%, 25%, 50%, 75% and 100%. Triplicate groups of 15 fish averaging 3.0 ± 0.02g (mean ± SD) and 8 fish averaging 14.03 ± 0.07g for experiments 1 and 2, respectively, were fed one of five experimental diets at 3% of total fish biomass.

The results obtained revealed clearly that all levels of SBM substitution (25, 50, 75 and 100%) by CM in both experiments are superior regarding all growth performance parameters compared to the control diet. However, fish fed diet with 100% CM substitution showed the lowest digestibility of CP, while those with 75% CM replacement had the poorest digestibility of EE, NFE and gross energy. Additionally, one of the key findings of the current study was that, canola meal did not introduce sufficient anti-nutritional factor to cause nutritional disorders, even when included in the diet at high levels as SBM substitute. The economic evaluation showed that diets containing higher levels of CM were less expensive and produced fish at lower cost per unit of body weight (kg) than diets containing higher levels of SBM in the experimental diets. Therefore, canola meal can be included up to 100% substitution level of SBM not only without negative affects but also to improve the productive performance of tilapia hybrid fingerlings.

Keywords: *canola meal, soybean meal, tilapia hybrid, productive performance, economic evaluation, digestibility.*

INTRODUCTION

Aquaculture is the fastest growing sector of world human food production and has an annual increase of about 10% (FAO, 1997). To sustain such a high rate of growth, a matching increase in fish feed production is imperative (Francis *et al.*, 2001). On the other hand, the high cost and fluctuating quality of fish meal as well as its uncertain availability (Alceste, 2000) have led to the need to identify alternative protein sources for fish feed. Considerable emphasis has been focused on the use of conventional plant protein sources, such as soybean (Sadiku and Jauncey, 1995), groundnut meal (Jackson *et al.*, 1982), cottonseed meal (El-Sayed, 1990; El-Kholy *et al.*, 2005) and rapeseed meal (Jackson *et al.*, 1982). However, their scarcity and competition from other sectors for such conventional crops for livestock and human consumption as well as industrial use make their costs too high and put them far beyond the reach of fish farmers or producers of aquafeeds (Fasakin *et al.*, 1999). Therefore, in order to attain a more economically sustainable, environmentally friendly and viable production, research interest has been directed towards the evaluation and use of unconventional protein sources, particularly from plant products such as seeds, leaves and other agricultural by-products (Olvera-Novoa *et al.*, 1988; El-Sayed, 1999; Siddhuraju and Becker, 2001).

Soybean meal (SBM) is a commonly used plant protein and is considered to be one of the most nutritious plant protein feedstuffs (Lovell, 1988). Growth has often been reduced in fish fed with soybean meal and one possible reason may be suboptimal amino acids balance relative to requirement of many cultured species (El-Dahhar and El-Shazli, 1993). Reports of growth and efficiency in tilapia fed soy products are conflicting (DeSilva and Gunasekera, 1989; El-Dahhar and El-Shazli, 1993). Poor performance is generally in direct relationship to level of soybean incorporation (Shiau *et al.*, 1990). Additionally, soybeans have anti-nutritional factors (ANFs) that reduce their biological value (Rackis, 1974; Liener, 1994). Those reported to decrease growth and efficiency in fish include proteinase inhibitors (Krogdahl *et al.*, 1994), antigens (Kaushik *et al.*, 1995), alcohol soluble components (Arnesen *et al.*, 1990; Olli and Krogdahl, 1995), lectin and agglutinin (Hendricks *et al.*, 1990), oligosaccharides (Rumsey *et al.*, 1995) and phytic acid (Spinelli *et al.*, 1983). Reduce palatability of feeds with high proportions of soy protein concentrate has been suggested as contributing to lower feed intake (Stickney *et al.*,1996) which could in turn cause reduced growth. On the other hand, soybean meal costs have been increased in last few years, so that aquaculturists have investigated a range of other plant meals as soybean meal replacers including sunflower meal or canola meal (Stickney *et al.*, 1996), and rapeseed meal (Shimeno *et al.*, 1993).

Canola is the name given to genetically selected varieties of rapeseed *Brassica napus* and *B. campestris* species that are low in both glucosinolates and antithyroid factors; less than 30 μmol of alkenyl glucosinolates per gram of oil free dry matter of seed; and erucic acid; less than 2% of total fatty acid in the oil (Bell, 1993). Canola meal (CM) is a particularly rich plant source of sulphur containing amino acids for fish diets (Higgs *et al.*, 1995) but its potential value as an ingredient in tilapia feed has received little attention. The quality of canola protein has also been judged by Higgs *et al.* (1988, 1990) to be equivalent to that of whole herring meal and higher than that of soybean meal and cottonseed meal using the essential amino acid index approach. However, CM does contain phenolic compounds such as sinapine and tannins that may reduce palatability (McCurdy and March, 1992) and protein digestibility (Krogdahl, 1989). It has a high fiber content which reduces protein and energy digestibility (Higgs *et al.*, 1983), and has some glucosinolates.

There have been few reports on the digestibility or nutritional value of varieties of canola meals when fed to fish species. From the reported studies, the response of fish to dietary inclusion of canola meal is generally favourable, although most authors list some reservations and restrictions to inclusion levels. In general, the nutritional value of canola meal for fish was reported to vary according to the amount of residual oil content of the meal, the levels of glucosinolates in the meal and the need to ensure that these glucosinolates do not impair circulating thyroid hormone levels and / or feed intake (Burel *et al.*, 2001).

The objective of this study was to determine the growth response and the nutrients digestibility of two sizes of tilapia hybrid (*Oreochromis niloticus* × *Oreochromis aureus*) fingerlings fed diets containing various levels of canola meal as a substitute for soybean meal of the percentage unit basis.

MATERIALS AND METHODS

Experimental system and animals:

The recent study included two parallel growth trials that were implemented simultaneous and at similar conditions. The experiments were carried out at Fish laboratory, Utilization of by-Products Department, Animal Production Research Institute, Ministry of Agriculture and Land Reclamation, Giza, Egypt from June 2003 to August 2003. Monosex tilapia hybrid (*Oreochromis niloticus* × *Oreochromis aureus*) fingerlings were obtained from private hatchery in Kafer El Shaikh Governorate and transferred to the fish lab and maintained in a 200L plastic tank to adapt the fish to the lab conditions until they reached a body weight of approximately 3g for experiment 1. For experiment 2, another group of the same tilapia hybrid also obtained from the above mentioned hatchery, was maintained in a separate 200L plastic tank until they reached a body mass of approximately 14g. The feeding trials were carried out in 60 l glass aquaria through a warmwater recirculating system. Dechlorinated city (tap) water was recirculated through biological and mechanical filters. Water exchange rate for the system was approximately 3% of total volume per day. Each aquarium was supplied with water at a rate of 2 l/min. Water temperature was maintained at 24 ± 1 °C. A constant photoperiod of 12-h light and 12-h dark was maintained. Rates of water flow were adjusted to maintain oxygen saturation above 80%. The water quality parameters in the system were monitored every other day and the ranges were: dissolved oxygen 6.5-8.0 mg l^{-1}, total ammonia 0.1-0.3 mg l^{-1}, and pH 6.8-8.2. No critical values were detected for nitrite (NO_2) and nitrate (NO_3) radicals. During the study, these averages were within acceptable limits for tilapia fish growth and health (Boyd, 1979).

Experimental diets:

Chemical composition of the ingredients used to formulate the experimental diets are presented in Table (1). Five experimental diets were formulated to contain various percentage of canola meal (CM) as partial or complete replacement for soybean meal in the control diet. They were used in both feeding experiments during the investigation period. The control diet (R_1) was formulated to be similar to a high quality commercial tilapia fish diet. Diets from R_2 to R_5 contained various percentages; 25, 50, 75 and 100%; of CM replacing soybean meal in the basal diet (Table 2). All the diets were formulated to be isonitrogenous (25.42 ± 0.4% CP) and isocaloric (4514 ± 122 Kcal GE/kg). In both feeding experiments, all fish were fed at 3% rate of total biomass by hand twice daily; 7 days per week; with care taken that no food was left uneaten. A record was kept of the amount of feed consumed by the fish in each aquarium.

Experimental procedure:

For experiment 1, a total of 225 fish were divided into five groups and each group had triplicates. Fifteen fish per replicate with initial mean body weight of 3.0 ± 0.02g were used. Whereas, in experiment 2, a total of 120 fish with an initial mean body weight of 14.03 ± 0.07g were used and were divided into

Table (1) : Chemical composition (% DM) of the ingredients used in the experimental diets.

Items	Yellow corn	Fish meal	Soybean meal	Canola meal
Dry matter (%)	89.0	92.0	90.0	93.0
Crude protein (%)	8.52	72.02	40.17	38.0
Ether extract (%)	3.7	8.2	2.1	5.8
Crude fibre (%)	2.5	0.5	7.2	10.2
Ash (%)	1.8	10.6	6.5	6.8
NFE (%)*	83.48	8.68	44.03	39.2
Gross Energy (Kcal/ kg)	3900	4780	4150	4150

* Calculated by difference

Table (2): Formulation and proximate analysis of the experimental diets (%DM) fed to tilapia hybrid (*Oreochromis niloticus* × *O. aureus*) fingerlings throughout the experiments.

Ingredient (%)	Experimental diets				
	R_1	R_2	R_3	R_4	R_5
	Control	25% CM	50% CM	75% CM	100% CM
Yellow corn	46.75	46.50	46.25	46.00	45.75
Fish meal (72.02% CP)	22.75	23.00	23.25	23.50	23.75
Soybean meal (40.17% CP)	24.00	18.00	12.00	6.00	0.0
Canola meal (38% CP)	0.0	6.00	12.00	18.00	24.00
Corn oil	3.50	3.50	3.50	3.50	3.50
Vit. & Min. mixture¶	2.00	2.00	2.00	2.00	2.00
Dried yeast	1.00	1.00	1.00	1.00	1.00
Total	100	100	100	100	100
Proximate analysis (%)					
DM	9.17	9.03	9.00	9.29	8.86
CP	25.66	25.04	25.84	25.26	25.32
EE	9.89	10.66	10.76	11.82	12.22
Ash	3.75	3.45	3.91	4.78	5.08
CF	9.71	8.44	8.13	9.19	7.23
NFE*	50.99	52.41	51.36	48.95	50.15
Gross Energy (Kcal/kg diet)	4424.00	4518.53	4531.18	4502.18	4591.37

¶ Each 1 Kg contains: Vit. A 4.8 mIU; E 4g; K 0.8 g; B_1 0.4 g; B_2 1.6g; B_6 0.6 g; B_{12} 4g; Pantothenic acid 4g; Nicotinic acid 8 g; Folic acid 400 mg; Biotin 20 mg; Choline chloride 299 g; Copper 4g; Iodine 0.4g; Iron 12g; Manganese 22g; Zinc 22g and Selenium 0.04g.
*Calculated by difference.

five groups and each group had triplicates of eight fish each. The fish were allowed to acclimate to the experimental system for a period of one week before starting the feeding trials. At the beginning of the two experiments, fish were individually weighed thereafter, fish were bulk. weighed weekly and feed amounts were adjusted for the subsequent week. Before starting the experiments, 20 fish of each of the respective populations were sampled for determination of initial body proximate composition. At the end of the experiments (90 days) the respective experimental fish were sacrificed and kept at –20 °C until analyze for final whole body composition.

Digestibility trials:

At the end of the feeding experiments, fish groups fed the experimental diets were subjected to digestibility trials. The diets were fed to fish groups twice a day for two weeks and the feces were collected by siphoning three hours after each added diet proportion. By using crude fiber as an inert marker in both the first and the second experiments, average apparent digestibility coefficients (ADC%) of nutrients (DM, CP, EE, NFE and gross energy) were calculated.

Sampling and analytical procedures:

All fish were weighed and length was measured individually at the start of the feeding trials. Whole body composition was determined in a pooled sample of 20 fish at the beginning and in pools of 5 fish per replicate at the end of growth trials. Feed ingredients, experimental diets, fish carcass and fecal materials were analyzed for proximate composition according to methods of AOAC (1995). Gross energy (GE) contents of the all samples were calculated according to Jobling (1983) using the multiplication factors of 4.0; 5.65 and 9.45 kcal GE/g for carbohydrate; protein and fat, respectively.

Calculations:

Data obtained were analyzed for initial body weight (IBW), final body weight (FBW), weight gain (WG), relative growth rate (RGR), feed intake (FI), feed conversion ratio (FCR), specific growth rate (SGR), protein utilization efficiency (PUE), protein productive value (PPV), fat productive value (FPV) and energy utilization (EU), liver indices (HSI), viscrasomatic index (VSI) and condition factor (CF).

Weight gain and efficiency parameters were calculated as:

- WG (g) = FBW - IBW
- RGR (%) = (FBW – IBW/ IBW) × 100
- FI (g) = Total dry matter feed intake
- FCR = FI / WG
- SGR (%/day) = [(ln FBW – ln IBW) / feeding days] × 100
- PUE = WG / protein intake
- PPV (%) = (Retained protein* /protein intake) × 100
- FPV (%) = (Retained fat* / fat intake) × 100
- EU (%) = (Retained energy* / energy intake) × 100

* Retained nutrient = Final fish body nutrient – initial fish body nutrient

- HSI (%) = (liver weight / body weight) × 100
- VSI (%) = (Viscra weight / body weight) × 100
- CF = [Body weight / (fish length)^3] × 100

Apparent digestibility coefficient (ADC%) of nutrients and gross energy were calculated from the formula:

- ADC (%) = 100 – 100 × [C_{ed} × CX_{ef} / CX_{ed} × C_{ef}]

Where:

ed is diet, ef is feces, C marker content and CX nutrient or energy content.

Economic evaluation:

The cost of diet to raise unit biomass of fish was estimated by a simple economic analysis. The estimation was based on total retail sale market price of all the dietary ingredients at the time of the study.

Statistical analysis:

Biological data obtained from the trials were subjected to statistical evaluation using one-way analysis of variance (ANOVA) of the general liner model (GLM) using SAS (1999) statistical package. Where means were significantly different ($P<0.05$), they were compared with Duncan's Multiple Range test (1955).

RESULTS AND DISCUSSION

Key differences were observed in the composition of the experimental diets (Table 2) used in this study. The main differences were the level of lipid content and sequentially the gross energy. The experimental diets were formulated to contain 25% CP. Analysis showed that dietary CP ranged from 25.04 to 25.84%. No relationship was observed between growth or performance and dietary CP level. Fish in the experiments were observed to be in good conditions of health and survival was around 95-97% in all groups. All tested diets were well accepted and consumed within 5 min after feeding. It is worth to mention that all levels of SBM substitution (25, 50, 75 and 100%) by CM in both experiments are superior to the control diet (R_1).

Productive performance

Experiment 1

In experiment 1, the results of growth performance of tilapia hybrid, *Oreochromis niloticus* × *O. aureus*, fingerlings (~ 3g) fed the tested diets are presented in Table (3). Fish fed diet 3 (R_3) substituting 50% SBM by canola meal had the best productivity values in terms of final body weight (FBW), weight gain (WG), relative growth rate (RGR), feed intake (FI) and specific growth rate (SGR). It is clear that there were improvement in the productive performance ($P< 0.05$) in fish groups fed diets 3 (50%CM) than fish fed diet 1 (0 %CM) and diet 4 (75%CM), but not significantly different ($P>0.05$) from those groups fed diet 2 (25%CM) and diet 5 (100%CM). Feed conversion ratio (FCR) of fish fed diet 3 (R_3) had the best value (2.50) comparable to the high value (2.98) obtained by fish group fed the control diet (R_1), however, there were no differences ($P>0.05$) in FCR among fish groups fed diets (4, 2, and 5). The trend for SGR was similar to FBW, WG and RGR.

No significant differences were detected in protein utilization efficiency (PUE) in all fish groups fed the experimental diets (Table 3). The results of protein productive value (PPV) show enhancement on fish productive indices when the level of SBM substitution was increased gradually. Fish groups fed diets (5 and 4) presented the highest values of PPV (17.99 and 16.17%, respectively), however, the difference was not significant. The reason for such high values may be due to the increase in retained protein determined in fish group fed diet 5. On the other hand, there were no significant differences in PPV between fish groups fed 50, 25 and 0% CM.

The FPV and EU of fish fed diet 5 (100% CM) was significantly greater than that found in fish groups fed all other tested diets including the control group ($P<0.05$), but there were no significant differences among those groups. The reasons for the obtained results of FPV may be due to the increase in retained fat and for EU may due to high lipid content (12.22%) detected in diet 5 (Table 2).

Experiment 2

The results of growth performance of tilapia hybrid fingerlings (~ 14g) fed the

Table (3): Growth performance parameters of tilapia hybrid (*Oreochromis niloticus* × *O. aureus*) fingerlings fed the experimental diets (Exp. 1).

Productive index	Experimental diets				
	R_1	R_2	R_3	R_4	R_5
	Control	25%CM	50%CM	75%CM	100%CM
IBW (g)	3.00 ± 0.0	2.98 ± 0.02	3.00 ± 0.0	3.00 ± 0.0	3.00 ± 0.0
FBW (g)	8.58^{c} ± 0.06	9.34^{abc} ± 0.15	10.31^{a} ± 0.52	8.87^{bc} ± 0.29	10.02^{ab} ± 0.59
WG (g)	5.58^{c} ± 0.06	6.36^{abc} ± 0.13	7.31^{a} ± 0.52	5.87^{bc} ± 0.29	7.02^{ab} ± 0.59
RGR (%)	186^{c} ± 2.11	213^{abc} ± 2.61	244^{a} ± 17.23	196^{bc} ± 9.70	234^{ab} ± 19.80
FI (g)	16.65^{b} ± 0.08	17.26^{ab} ± 0.24	18.24^{a} ± 0.58	16.46^{b} ± 0.24	17.82^{a} ± 0.38
FCR	2.98^{b} ± 0.02	2.71^{ab} ± 0.09	2.50^{a} ± 0.2	2.80^{ab} ± 0.1	2.54^{ab} ± 0.18
SGR (%/day)	1.17^{c} ± 0.01	1.27^{abc} ± 0.01	1.37^{a} ± 0.06	1.21^{bc} ± 0.04	1.34^{ab} ± 0.07
PUE	1.31 ± 0.01	1.47 ± 0.04	1.55 ± 0.12	1.41 ± 0.05	1.56 ± 0.10
PPV (%)	13.61^{c} ± 0.08	13.75^{c} ± 0.42	14.66^{bc} ± 1.05	16.17^{ab} ± 0.48	17.99^{a} ± 1.01
FPV (%)	12.55^{b} ± 0.07	12.40^{b} ± 0.37	14.18^{b} ± 0.99	12.46^{b} ± 0.37	16.30^{a} ± 0.87
EU (%)	7.11^{b} ± 0.04	7.07^{b} ± 0.21	7.90^{b} ± 0.56	8.24^{b} ± 0.24	9.71^{a} ± 0.54

a, b, c etc: Means in the same row with different superscripts are significantly different ($P < 0.05$).

experimental diets in experiment 2 are shown in Table (4). The growth of fish groups fed diets containing canola meal (R_2 to R_5) were significantly greater than that noted for fish group fed the control diet (R_1).

Fish groups fed diets (3, 4, 5 and 2) that containing 50, 75, 100 and 25%CM to replace SBM in the control diet had the best growth performance values in terms of FBW, WG and better values of FCR ($P<0.05$), however, there were no significant differences between R_1 and R_2 except in FCR, where the difference was significant ($P<0.05$) among both groups. Similar results are obtained ($P<0.05$) from figures of RGR and SGR for fish fed diets contain CM in order of (R_4, R_3, R_5 and R_2). It is noted that feed intake increased when the level of SBM substitution by CM was increased. It means that diets containing CM had more palatability than diets contained SBM.

The groups of fish fed diet 3 (50%CM) followed by diets (4, 5 and 2) showed the highest ($P<0.05$) values of protein utilization efficiency, while the control diet (0%CM) showed the lowest value (1.06) of PUE. Fish groups fed R_5, R_3 and R_2 showed the highest values ($P<0.05$) of PPV and EU. Records of FPV presented in Table (4) show that fish fed diets (3, 5 and 2) had the higher values ($P<0.05$) of FPV. However, the lowest values of all parameters were obtained by group fed the control diet (R_1).

Concerning the productive performance of tilapia hybrid fingerlings (3 and 14g), results obtained are in accordance with those obtained by Riche and Garling (2004). They quoted that although soybean meal has a favourable indispensable amino acid (IAA) profile for replacing FM, particularly at high rates of incorporation, the diet can become deficient in IAA, leading to inhibition of protein digestibility or absorption of one or more IAA which will depress growth and feed efficiency. Also, Nile tilapia are sensitive to soybean trypsin inhibitors (TIA).

The lack of any adverse effect due to incorporation CM on fish growth is perhaps one of the key findings of the current study. It shows that under the dietary inclusion levels used, canola meal did not introduce sufficient anti-nutritional factors to cause problems, even when included in the diet up to 100% of SBM substitution. These positive effects of the present study are in agreement with those obtained by many workers. A small inclusion of plant protein in tilapia diets results in increased growth efficiency. Substitution of copra, groundnut, SBM and rapeseed for FM at 25% CP diet increased weight gain and performance of Mozambique tilapia, *Oreochromis mossambicus* (Jackson *et al.*, 1982). Increased growth performance is attributed to improving IAA patterns with plant proteins incorporated at 25% CP diet (Dabrowski *et al.*, 1989). However, in the study of Higgs *et al.* (1983), the inclusion of canola meal in protein-limiting and high-nutrient diets displayed differences in the performance of fish. The differences between the current study and the obtained results by Higgs *et al.* (1983) may be due to the method of oil extraction from canola seed which can influence the glucosinolate and decomposition-product levels of the meal (Anderson *et al.*, 1993). It is worthy to mention that canola meal used in the present investigation has submitted to expeller processing only, therefore, the obtained canola meal had higher lipid content than the solvent-extracted meal which is commonly present in imported canola meal. Consequently, more total digestible energy may be noticed in fish responses fed expeller canola meal like that used in the current experiments. This explanation generally agrees with the

Table (4): Growth performance parameters of tilapia hybrid (*Oreochromis niloticus* × *O. aureus*) fingerlings fed the experimental diets (Exp. 2).

Productive index	Experimental diets				
	R_1	R_2	R_3	R_4	R_5
	Control	25%CM	50%CM	75%CM	100%CM
IBW (g)	14.33 ±0.22	14.08 ±0.47	14.50 ±0.22	14.13 ±0.19	14.09 ±0.15
FBW (g)	29.90 ^{b} ±1.17	34.13 ^{ab} ±0.82	37.68 ^{a} ±1.81	36.83 ^{a} ±0.50	36.03 ^{a} ±1.91
WG (g)	15.57 ^{b} ±1.14	20.05 ^{ab} ±1.20	23.18 ^{a} ±1.95	22.70 ^{a} ±0.47	21.94 ^{a} ±2.02
RGR (%)	109 ^{b} ±8.16	142 ^{ab} ±12.67	160 ^{a} ±15.34	161 ^{a} ±4.08	156 ^{a} ±15.74
FI (g)	57.29 ^{b} ±1.22	58.04 ^{b} ±0.78	61.77 ^{a} ±0.49	62.67 ^{a} ±0.03	62.76 ^{a} ±2.00
FCR	3.68 ^{b} ±0.28	2.90 ^{a} ±0.20	2.67 ^{a} ±0.21	2.76 ^{a} ±0.06	2.86 ^{a} ±0.17
SGR (%/day)	0.82 ^{b} ±0.04	0.98 ^{a} ±0.06	1.06 ^{a} ±0.06	1.07 ^{a} ±0.02	1.04 ^{a} ±0.07
PUE	1.06 ^{b} ±0.08	1.38 ^{a} ±0.10	1.45 ^{a} ±0.12	1.44 ^{a} ±0.03	1.38 ^{a} ±0.08
PPV (%)	15.41 ^{c} ±0.93	21.10 ^{ab} ±1.21	22.30 ^{ab} ±1.51	17.74 ^{b} ±0.37	24.09 ^{a} ±1.06
FPV (%)	10.91 ^{c} ±0.65	13.46 ^{ab} ±0.77	14.97 ^{a} ±1.00	12.03 ^{bc} ±0.23	14.19 ^{ab} ±0.61
EU (%)	7.42 ^{c} ±0.44	9.64 ^{ab} ±0.55	10.69 ^{ab} ±0.71	9.20 ^{b} ±0.17	11.10 ^{a} ±0.48

a, b, c etc: Means in the same row with different superscripts are significantly different ($P < 0.05$).

digestibility results reported by Glencross *et al.* (2004).

Many researches were gone contrary to the present study. Webster *et al.*(1997) reported that channel catfish fed a diet containing 48% CM had inferior FCR (2.24) than fish fed diets containing 12, 24 and 36% CM which recorded FCR values of 1.75, 1.82 and 1.89; respectively. Higges *et al.* (1983) reported that growth and feed consumption were reduced in Chinook salmon fed diets where CM partially replaced herring meal. Hilton and Slinger (1986) stated that reduced growth of rainbow trout fed CM based diets was due to reduced diet intake.

Additionally, Maga (1982) stated that phytates, the anionic forms of phytic acid existed in soybean, bind divalent cations making them unavailable. Reduced minerals bioavailability has been demonstrated in fish fed diets containing phytates (Forster *et al.* 1999; Papatryphon *et al.* 1999). Phytates also form complexes with proteins which reduce the availability of AAs (Reddy *et al.* 1989). In acidic environment, such as the tilapia stomach (pH 1.0-2.0), half of phosphate moieties are negatively charged. This favours binding of soluble proteins at ε-amino groups of lysine, imidazole groups on histidine and gaunidyl groups on arginine. In alkaline environment, such as tilapia intestine (pH 8.5-8.8), ternary complexes (phytate-mineral-protein) are favoured. Both binary complexes (phytate-protein) and ternary complexes (phytate-mineral-protein) are resistant to proteolytic digestion (Vaintraub and Bulmaga, 1991; Caldwell, 1992).

Bell (1993) mentioned that canola meal contains about 1.22% total P of which 0.53% is phytate-bound. The corresponding values for SBM are about 0.66 and 0.38%, indicating that CM provides about twice as much non-phytate P compared to SBM

The results of this study clearly show that canola meal can be included in diets of tilapia hybrid up to 100% substitution level of SBM without affecting the growth rate and feed and protein utilization. These results are similar to those obtained by Glencross *et al.* (2004). They showed that under the dietary inclusion levels used in their study, the canola meals did not introduce sufficient anti-nutritional factors to cause problems, even when included in the diet at levels more than 60% of the total diet. On the other hand, results of the present study are in contrast with those of numerous other studies, most of which have observed depressed fish growth with the inclusion of high dietary levels of canola or rapeseed meals. Usually, this depressed growth occurred as a result of reduced feed intake associated with metabolic depression induced by glucosinolate breakdown products interfering with thyroid hormone metabolism or high concurrent intakes of other antinutritional factors present in the canola meal (Higgs *et al.*, 1982; Burel *et al.*, 2001).

Whole body composition and liver index:

Experiment 1

Whole body composition, HSI, VSI and CF of tilapia hybrid fingerlings at the beginning and the end of experiments 1 and 2 are given in Table (5). In experiment 1, fish fed diet 5 (100%CM) had a significantly lower ($P<0.05$) percentage of body moisture (79.99%) than fish fed the other diets. It was noted that with increasing inclusion level of CM in the diets up to 75% (R_4), there was a general concomitant increase in protein content ($P<0.05$). The differences in lipid content between each of the treatments were also reflected in the energy contents of fish. Ash content was

Table (5) : Whole-body composition (%DM), HSI, VSI and CF of tilapia hybrid (*Oreochromis niloticus* × *O. aureus*) fingerlings fed the experimental diets (Experiments 1 and 2).

	Experiment 1						Experiment 2					
	Final carcass composition					Initial carcass composition	Final carcass composition					Initial carcass composition
	R_1	R_2	R_3	R_4	R_5		R_1	R_2	R_3	R_4	R_5	
	Control	25% CM	50% CM	75% CM	100% CM		Control	25% CM	50% CM	75% CM	100% CM	
Moisture (%)	82.13^{d}	83.41^{b}	83.19^{c}	81.10^{e}	79.99^{f}	86.03^{a}	74.52^{c}	72.78^{d}	72.55^{d}	75.08^{b}	72.07^{e}	78.47^{a}
CP (%)	52.11^{c}	52.32^{c}	52.42^{b}	53.14^{a}	51.35^{e}	52.03^{d}	48.00^{b}	47.72^{c}	48.02^{b}	48.54^{b}	51.64^{a}	45.11^{d}
Lipid (%)	18.46^{d}	19.59^{c}	20.42^{b}	19.09^{c}	21.15^{a}	18.11^{e}	12.95^{c}	12.86^{c}	13.22^{b}	13.66^{b}	14.41^{a}	11.92^{d}
Ash (%)	17.31^{c}	21.47^{a}	17.63^{c}	17.13^{c}	14.67^{d}	20.05^{b}	21.56^{a}	20.31^{b}	20.74^{b}	20.39^{b}	19.55^{c}	21.48^{a}
GE (Kcal / kg)	4688.69^{d}	4807.34^{c}	4891.42^{b}	4806.42^{c}	4933.97^{a}	4651.09^{e}	3935.78^{d}	3911.45^{e}	3962.42^{c}	4033.38^{b}	4279.41^{a}	3675.16^{f}
HSI	5.36	3.93	4.57	4.55	3.81	NC	2.01	2.44	2.52	2.16	3.50	NC
VSI	11.87	13.19	12.26	11.49	11.10	NC	5.94^{b}	7.99^{a}	7.43^{ab}	8.82^{a}	7.57^{ab}	NC
CF	0.98	0.97	0.98	1.13	1.28	NC	0.72	0.68	0.92	0.64	0.75	NC

a, b, c etc: Means in the same row with different superscripts are significantly different ($P< 0.05$), NC: not calculated.

variable between the experimental diets and resulted in a significantly higher value in diet 2 (21.47%) than the control diet (17.31%).

The liver index (HSI%) was not significantly (P>0.05) affected among the experimental fish groups, and in most groups the largest change in liver index (3.81 and 5.36) was found in fish fed R_5 and R_1, respectively. The liver indices of fish fed the experimental diets (Table 5) were not affected by the high lipids content of whole body. It means that all levels of SBM substitution by CM did not affect the liver functions of the experimental fish groups. The results of VSI (%) changed little during the trials (P>0.05). The condition factor (CF) varied between 0.97 and 1.28, however, no significant differences were noticed among all fish groups.

Experiment 2

In Table (5), fish group fed diet 5 (100%CM) showed the higher protein, lipid and energy on their body content, while fish fed diet (1) had the higher ash content (21.56%). However, with regard to the moisture content, a significantly lower level was recorded in fish fed diet 5 (100%CM).

HSI and CF were not significantly affected in the experimental fish groups, whereas, VSI was clearly increased in fish groups fed diets containing CM.

Digestibility trials:
Experiments 1 and 2

Nutrients digestibility in experiments (1 and 2) of tilapia hybrid fed the tested diets are shown in Table (6). For both experiments, the results of DM, NFE and gross energy digestibility of group fed 25% CM (R_2) show the higher values (96.89, 73.98 and 80.89%; 96.42, 72.86 and 80.04%, respectively), while, fish group fed the control diet (0% CM) presented the higher value of EE digestibility (91.45 and 92.55% in experiment 1 and 2 , respectively). On the other hand, fish fed diet 3 (50% CM) had the highest value of CP digestibility (84.68 and 83.60% in experiment 1 and 2, respectively). However, fish fed diet 5 (100% CM) showed the lowest digestibilities of DM and CP. Likewise, fish fed diet 4 (75% CM) had the poorest digestibilities of EE, NFE and gross energy, compared to those fed the other diets in both experiments.

Previous studies of Anderson *et al.* (1991) have indicated that in tilapia as in other species (Lupatsch *et al.* 1997) CP digestion is relatively high and this is found even in feeds containing high fiber. Fat digestibility in other species ranged from 70% to 90% (Lupatsch *et al.* 1997) and similar values were found in the hybrid tilapia in the study of Sklan *et al.* (2004). DE values for different fish species vary depending on the nature of the digestive tract and type of digestive enzymes secreted (Buddington and Hilton 1987).

Study by Glencross *et al.* (2004) assessed the nutrient and energy digestibility of a variety of canola protein products that were produced by processing canola meal under different conditions, using the red seabream, *Pagrus auratus*. They concluded that both expeller and solvent-extracted canola meal have a reasonable digestible value, but no significant differences were noted in the digestible value of each of the different canola meal types. A decline in the digestibility of most nutrients was observed with increasing heat exposure.

Economic evaluation:
Experiments 1 and 2

Average relative diet costs, diet ingredients costs and costs of gain including only diet ingredient costs are shown in Table (7).

Feeding costs in fish production represent about 50% of the total production costs (Collins and Delmendo 1979). All other costs in the present study

Table (6) : Nutrients digestibility (% DM) of tilapia hybrid (*Oreochromis niloticus* × *O. aureus*) fingerlings fed the experimental diets (Experiments 1 and 2).

Nutrients	Experiment 1					Experiment 2				
	Experimental diets					Experimental diets				
	R_1	R_2	R_3	R_4	R_5	R_1	R_2	R_3	R_4	R_5
	Control	25%CM	50%CM	75%CM	100%CM	Control	25%CM	50%CM	75%CM	100%CM
DM	96.80^b	96.89^a	96.29^c	95.63^d	95.61^e	95.80^c	96.42^a	95.97^b	93.89^d	93.84^e
CP	80.93^c	83.75^b	84.68^a	77.16^d	76.54^e	83.25^b	82.29^c	83.60^a	77.97^d	76.96^e
EE	91.45^a	91.26^b	90.33^d	88.30^e	90.59^c	92.55^a	91.79^b	91.69^c	87.56^e	88.45^d
NFE	68.49^c	73.98^a	73.50^b	59.37^e	60.28^d	70.52^b	72.86^a	70.50^c	56.77^e	60.23^d
Energy	77.42^c	80.89^a	80.87^b	72.19^e	72.97^d	79.34^c	80.04^a	79.47^b	71.13^e	72.54^d

a, b, c etc: Means in the same row with different superscripts are significantly different ($P < 0.05$).

Table (7): Average relative diet costs, diet ingredient costs and costs of gain including only diet ingredient costs.

Nutrients	Experiment 1					Experiment 2				
	Experimental diets					Experimental diets				
	R_1	R_2	R_3	R_4	R_5	R_1	R_2	R_3	R_4	R_5
	Control	25%CM	50%CM	75%CM	100%CM	Control	25%CM	50%CM	75%CM	100%CM
Diet cost (LE/kg)*	2.55	2.50	2.45	2.39	2.34	2.55	2.50	2.45	2.39	2.34
Relative diet cost %	100	98	96	93	91	100	98	96	93	91
Cost gain (LE/kg gain)**	7.60	6.78	6.13	6.69	5.94	9.38	7.25	6.54	6.38	6.69
Relative cost of gain	1.0	0.89	0.81	0.88	0.78	1.0	0.77	0.70	0..68	0.71

* Local market price of (LE/ton) of feed ingredients used in formulating the experimental diets are: yellow corn, 900; fish meal herring, 6000; soybean meal, 1700; canola meal, 600; corn oil, 4000; vit. & min mixture, 10000 and dried yeast, 2000.

** Cost of gain = diet cost (LE. Kg^{-1}) × Feed conversion ratio are constant. therefore. the feeding costs required to produce one kg gain in weight could be used to compare the differences among experimental treatments. Results presented in Table (7) show that incorporation of CM in replacement of SBM at levels of 25 to 100% reduced the diets costs between 2 to 9%. In experiment 2, diets 2, 3, 4 and 5 were: 2, 4, 7 and 9% less expensive than the control diet in both experiments. The economic analysis showed that diets containing higher levels of CM were less expensive and produced fish at lower cost per unit of weight (kg) than diets containing higher levels of SBM in diet 1. Based on these data. the diets containing CM in tilapia hybrid appears to be the most effective and economical substitute for SBM.

CONCLUSION

The results obtained from the current study show that canola meal (CM) has better protein quality comparable to soybean meal (SBM) and is generally less expensive than SBM on a unit protein basis. Additionally, increasing dietary canola meal substitution for soybean meal did not affect negatively growth performance and feed utilization efficiency of tilapia hybrid fingerlings. On contrary, canola meal improves tilapia fish growth performance.

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إحلال كسب الكانولا محل كسب فول الصويا في علائق إصبعيات البلطى الهجين (بلطى نيلى × بلطى أوريا).

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قسم بحوث إستخدام المخلفات، معهد بحوث الإنتاج الحيواني، مركز البحوث الزراعية، وزارة الزراعة، الجيزة، ج م ع.

أجريت تجربتين غذائيتين لمدة ٩٠ يوما لتقييم إمكانية الإستبدال الجزنى أو الكلى لكسب فول الصويا بكسب الكانولا فى علائق إصبعيات البلطى الهجين (بلطى نيلى × بلطى أوريا). تم تكوين خمسة علائق متشابهة فى محتواها من البروتين الخام (٢٥,٤٪) والطاقة الكلية (٤٥١٤ كيلو كالورى) فى كل من التجربتين حيث تم إحلال كسب الكانولا محل كسب فول الصويا بمستويات صفر، ٢٥ ، ٥٠ ، ٧٥ ، ١٠٠٪ وقدمت العلائق للأسماك بمعدل ٣٪ من وزن الجسم فى ٣ مكررات حيث إستخدم ١٥ سمكة لكل مكرر بمتوسط وزن ٣ ± ٠٢, جرام، ٨ سمكات بمتوسط وزن ٠٣, ١٤ ± ٠٧, جرام للتجربة الاولى والثانية على التوالى.

أوضحت نتائج النمو والأداء الإنتاجى تفوق جميع مستويات إحلال كسب الكانولا محل كسب فول الصويا فى كل من التجربتين مقارنة بعليقة المقارنة. ومن أهم النتائج المتحصل عليها أن كسب الكانولا لا يحتوى على مواد مضادة للتغذية بالقدر الذى يؤدى إلى حدوث مشاكل تغذوية حتى عند إحلاله محل كسب فول الصويا بمستويات مرتفعة. ومع ذلك فقد سجلت الأسماك المغذاه على ١٠٠٪ كسب كانولا أقل معدل لهضم بروتين الغذاء بينما سجلت الأسماك الغذاه على ٧٥٪ كسب كانولا أقل معدل لهضم الدهن والكربوهيدرات والطاقة الكلية فى الغذاء. كما أظهر التقييم الإقتصادى أن العلائق المحتوية على نسبة أعلى من كسب الكانولا كانت أقل تكلفة لإنتاج كيلوجرام عليقة وكذلك لانتاج ١ كيلوجرام من وزن الأسماك مقارنة بالعلائق المحتوية على مستويات أعلى من كسب فول الصويا بالعلائق التجريبية. ولذلك يمكن إستبدال كسب الكانولا محل ١٠٠٪ من كسب فول الصويا ليس فقط بدون تأثير سلبى ولكن بالعكس تحسن الأداء الإنتاجى لإصبعيات البلطى الهجين.