



Original Research Article

Utilization of autoclaved and fermented sesame (*Sesamum indicum* L.) seed meal in diets for Til-aqua natural male tilapia



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ABSTRACT

Current research emphasis has been on the reduction of feed cost by incorporating processed sesame seed meal in the diet of tilapia. Raw sesame (*Sesamum indicum*) seed was soaked and subjected to either autoclaving or fermentation, after which their oil contents were mechanically extracted. Graded levels of autoclaved (71.2, 165.5 and 296.3 g/kg designated as diets 1, 2 and 3, respectively) and fermented (71.0, 164.3 and 292.2 g/kg designated as diets 4, 5 and 6, respectively) sesame seed meal were included into fishmeal based diets for Til-aqua natural male tilapia (NMT) fry (initial weight, 1.69 ± 0.02 g). A diet without sesame seed meal served as the control. Diets were approximately iso-nitrogenous (35% crude protein). Fish were fed 5 times their maintenance requirement, which was $3.2 \times 5 \times$ [fish weight (g)/1,000]^{0.8} daily for 56 days. Processing improved the nutritional profile of raw sesame seed meal in terms of its crude protein and antinutrient compositions. Growth performance of fish was similar ($P > 0.05$) in the control and dietary treatments. The group fed diet 3 exhibited significantly poorer feed conversion ratio (1.14), protein efficiency ratio (2.77) and economic conversion ratio (US\$1.38/kg) relative to the group that received diet 5. Apparent digestibility coefficients for protein, lipid and energy in diet 3 were similar ($P > 0.05$) to those in diet 6 but significantly lower ($P < 0.05$) than those of the control and other dietary groups. The sesame seed meals processed with different methods did not significantly affect crude protein, crude lipid and gross energy compositions in the fish carcass. The study demonstrated that 71.2 g/kg of autoclaved and 164.3 g/kg of fermented sesame seed meal could be incorporated in the diet of Til-aqua NMT with cost benefit.

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1. Introduction

The demand for fish feed has continued to increase as a result of growing global aquaculture production which reached an all-time high of 60 million tonnes (1 tonne = 1,000 kg) in 2010 (FAO, 2012). The challenge of fish feed industry is to formulate quality

fish feeds that meets the nutritional requirements of fish and also minimise production cost, limit environmental impacts and enhance products quality (Guo et al., 2011; Evans et al., 2005) using non-conventional sources of protein from both plant and animal origins. Less expensive plant protein feedstuffs such as soybean meal (Evans et al., 2005), lupins (Glencross et al., 2008) and various oilseeds (El-Saidy and Saad, 2008; Guo et al., 2011) have been widely explored. Many authors have however reported that constraints such as low crude protein content, deficiency of key amino acids, low digestibility, the presence of high amounts of carbohydrate, fiber and other antinutritional factors, decreased palatability and limited their overall nutritive value and inclusion in practical feeds (Francis et al., 2001; Refstie et al., 2005; Dongmeza et al., 2006). To encourage the incorporation of non-conventional protein sources in fish feed at high inclusion level, efforts are geared towards the enhancement of their nutritive value through

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processing to increase the bioavailability of nutrients and reduce or remove their antinutritional factors (Francis et al., 2001; Refstie et al., 2005).

Sesame (*Sesamum indicum*) is cultivated primarily for its oil (Lee et al., 2010), with substantial oilcake generated as a by-product which could be utilized as source of dietary protein in animal feeds including fish (Guo et al., 2011; Nang Thu et al., 2011). In 2012, about 4.04 million tonnes of sesame seeds were produced globally having risen from 1.4 million metric tonnes in 1960 (FAO, 2013); the bulk of which came from Asian and African countries. Nigeria's production of the crop consistently increased from about 15,000 metric tonnes in 1980 to about 158,000 metric tonnes in 2012 (FAO, 2013). USAID (2009) had earlier suggested a vast potential for increased production in Nigeria owing to large expanse of suitable land available to grow the crop.

This study was conducted to assess the effects of soaking, followed by either autoclaving or fermentation on the nutritive value of sesame seed and also evaluate the potential of the processed meals in the diet of Til-aqua red natural male tilapia (NMT) fry.

2. Materials and methods

2.1. Experimental system and fish

The experiment was conducted at the fish hatchery of Durante Fish Industries Limited, Old Nigerwest Building, Orita Challenge, Ibadan, in 14 recirculating systems. The recirculating system consists: plastic rearing tanks (1.10 m × 0.9 m × 0.45 m) which carries 2 cylindrical filter blocks (diameter: 0.3 m, height: 0.3 m) in a pipe (diameter: 0.31 m, height: 0.71 m); an ultraviolet compartment consisting of an 11-W bulb with its transformer and glass casing; 2 sedimentation (0.66 m × 0.30 m × 0.54 m) and pump units (0.66 m × 0.30 m × 0.54 m) with their filter blocks (0.6 m × 0.25 m × 0.3 m) and submersible pumps (Aquamaxima; 7,500 L/h). The systems were supplied with water from an overhead 7,500 L-capacity reservoir.

Til-aqua red NMT (average weight of 280 fish = 1.69 ± 0.02 g) used in the present study were produced using *Oreochromis niloticus* individuals that have 2Y chromosomes (YY) and no X chromosome. The YY male was produced using the technique described by Subasinghe et al. (2003), except that temperature rather than hormone was used to sex reverse normal (XY) male. The YY line was then crossed with normal female (XX) from a separate normal mixed sex line to produce NMT. The fry were randomly distributed into 14 systems at the density of 40 fish per system. The design of the experiment was completely randomized and each treatment was duplicated. Experimental fish were batch-weighed with a top-loading balance (RCL-15) at the start and weekly till the end of the experiment.

2.2. Feed ingredients and preparations

All feed ingredients were from Durante Feed Mill (New Garage, Ibadan, Nigeria) except for the sesame seeds, which were collected from the Institute of Food Security, Environmental Resources and Agricultural Research (IFSERAR) of the Federal University of Agriculture, P.M.B. 2240 Abeokuta, Nigeria. The seeds were cleaned and a portion (unprocessed) was kept for biochemical analysis. The remaining seeds were soaked in water (1:4, wt:vol) for 24 h at room temperature (30°C) according to Mukhopadhyay and Ray (1999a,b). Water temperature and pH were monitored 8-hourly during soaking. Subsequently, the seeds were divided into 2 portions and a portion was autoclaved using Prestige Clinical Autoclave (Series 2100) at 121°C and 15 psi (1.05 kPa/cm²) for 30 min (Siddhuraju and Becker, 2001). The autoclaved seeds were

dried in a Binder (FO 115, Germany) drying cabinet at 100°C for 2 h, finely ground using a locally fabricated hammer mill and screw-pressed with an improvised mechanical screw-press for 6 h. The other portion of the soaked sesame seeds were dried in a Binder (FO 115, Germany) oven at 100°C for 2 h and finely ground using a locally fabricated hammer mill after which it was subjected to solid state fermentation for 48 h at room temperature (30°C) using *Lactobacillus plantarium* at the Department of Microbiology, Federal University of Agriculture, P.M.B. 2240 Abeokuta, Nigeria according to the method described by Mukhopadhyay and Ray (1999b). The pH and temperature of the medium were monitored periodically. The oil from the fermented sample was also extracted as previously described. The resultant cake from the autoclaved and fermented samples were pulverized and passed through a fine mesh sieve (595 µm) to ensure homogeneity.

Seven approximately isonitrogenous (35% crude protein) diets were formulated (Table 1). There was a control diet without any of the processed sesame seed meal, but diets designated as diets 1 to 6 contained graded levels of autoclaved (71.2, 165.5 and 296.3 g/kg) and fermented (71.0, 164.3 and 292.2 g/kg) sesame seed meal (Table 2). Chromic oxide was used at 0.5% in all the experimental diets as an inert marker to determine the digestibility coefficient of nutrients in the diets. The ingredients were properly sieved using a 595 µm sieve to remove chaff and ensure homogenous size profile, thoroughly mixed and pelleted through a 2 mm die using hand pelletizer (unbranded). The pellets were sundried at an average temperature of 42°C for a day, packed in properly labeled cellophane bags and stored in a refrigerator at 4°C before the commencement of the feeding trial.

2.3. Fish maintenance and sample collection

The fish were fed 5 times their maintenance requirement $\{5 \times 3.2 \times [\text{fish weight (g)}/1,000]^{0.8}\}$ per day according to Kumar et al. (2010). The daily rations were offered in 2 equal portions at 09:00 and 16:00. The fish were fed daily except the day when they were weighed. The quantity of feed was adjusted according to the weekly weight gain and the experiment lasted for 56 days. Water temperature ($27.83 \pm 0.05^\circ\text{C}$), pH (8.09 to 8.36) and conductivity (0.056 ± 0.01 S/m) were measured using calibrated combined meter (Combo, Hanna). A pond lab oxygen test kit was used to measure dissolved oxygen (9.33 ± 0.44 mg/L). Nitrite (0.08 ± 0.08 mg/L) was monitored using a Colombo nitrite test kit, and ammonia was not detected using Merck (Germany) ammonium test kit. Fish faeces were collected daily for 2 weeks to the end of the experiment. One hour after the feed was administered; any feed and faeces present in the tank was removed. Fresh faeces produced by the fish after this period and before the second feed was given were siphoned immediately according to replicates to minimize leaching of nutrients into water. The collected faeces were filtered onto filter paper and dried at 105°C for 2 h. The faecal samples from each replicate tank were pooled according to treatment and stored in tagged cellophane bags in a freezer at -10°C . Based on chromic oxide content of the diet and nutrient content of the diet and faeces, digestibility coefficients for feed protein, energy and lipid were determined using the acid digestion method of Furukawa and Tsukahara (1966) and calculated using the relationship: Apparent digestibility coefficient (ADC, %) = $100 - [100 \times (\% \text{Cr}_2\text{O}_3 \text{ in diet} \times \% \text{nutrient/energy in faeces}) / (\% \text{Cr}_2\text{O}_3 \text{ in faeces} \times \% \text{nutrient/energy in diet})]$. Five fish were collected at the start of the experiment and also at the end from each replicate of the dietary treatments, killed by decapitation and stored in tagged polythene bag in a freezer at -10°C for subsequent biochemical analysis.

Table 1

Proximate composition (g/kg), gross energy (kJ/g) and anti-nutritional composition (g/kg) of feed ingredients used in diet formulation.

Item	Fish meal	Wheat meal	Raw sesame	Autoclaved sesame	Fermented sesame
Moisture	52.5	101.4	30.8	23.4	33.5
Crude protein	672.1	135.0	180.2	230.0	244.3
Ether extract	148.0	19.1	474.6	400.0	388.1
Crude fiber	–	–	37.2	29.0	21.2
Ash	126.6	16.6	77.7	63.0	70.2
NFE	0.8	680.6	199.5	254.6	242.7
Gross energy	21.60	16.41	26.59	25.70	25.24
Anti-nutritional composition					
Tannins	–	–	15.0	0.3	0.2
Phytic acid	–	–	7.2	4.9	6.0
Oxalate	–	–	5.8	5.2	5.6
Total reducing sugar	–	–	86.1	74.9	63.1

NFE = nitrogen free extract.

Table 2Ingredients, chemical and antinutritional composition of experimental diets¹.

Item	Control	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Ingredient, g/kg							
Fishmeal	416.7	403.6	386.2	362.1	402.2	383.2	357.2
Autoclaved sesame	–	71.2	165.5	296.3	–	–	–
Fermented sesame	–	–	–	–	71.0	164.3	292.2
Wheat meal	518.3	460.2	383.3	276.6	461.8	387.5	285.6
Fish oil	30	30	30	30	30	30	30
Premix ²	20	20	20	20	20	20	20
Lignobond	10	10	10	10	10	10	10
Chromic oxide	5	5	5	5	5	5	5
Chemical composition, g/kg							
Moisture	35.3	64.0	63.8	53.1	24.7	50.3	48.6
Crude protein	349.5	350.2	346.0	349.6	349.4	349.7	349.9
Ether extract	101.6	127.0	160.7	207.3	125.9	157.9	201.7
Crude fiber	16.7	15.0	14.5	12.1	16.0	13.4	12.6
Ash	99.2	92.1	96.2	97.1	99.0	98.2	99.6
Nitrogen free extract	397.7	351.7	318.8	284.8	385.0	330.5	287.6
Gross energy, kJ/g	19.28	19.46	20.08	21.24	19.98	20.24	21.19
Antinutritional composition, g/kg							
Tannins	–	0.02	0.05	0.09	0.01	0.03	0.06
Phytic acid	–	0.3	0.8	1.5	0.4	1.0	1.8
Oxalate	–	0.4	0.9	1.5	0.4	0.9	1.6
Total reducing sugar	–	5.3	12.4	22.3	4.5	10.4	18.4

¹ The control diet was without any of the processed sesame seed meal, but diets designated as diets 1 to 6 contained graded levels of autoclaved (71.2, 165.5 and 296.3 g/kg) and fermented (71.0, 164.3 and 292.2 g/kg) sesame seed meal.

² Hi-nutrient vitamin premix supplied per 100 g diet: vitamin A palmitate, 1,000 IU; cholecalciferol (D), 1,000 IU; α -tocopherol acetate (E), 1.1 mg; menadione (K), 0.02 mg; thiamine B₁, 0.63 mg; riboflavin (B₂), 0.5 mg; pantothenic acid, 1.0 mg; pyridoxine (B₆), 0.15 mg; cyanocobalamin (B₁₂), 0.001 mg; nicotinic acid, 3.0 mg; folic acid, 0.1 mg; choline, 31.3 mg; ascorbic acid (C), 0.1 mg; ferrous sulfate, 0.05 mg; copper sulfate, 0.25 mg; manganese sulfate, 6.00 mg; cobalt chloride, 0.5 mg; zinc sulfate, 5.0 mg; sodium selenite, 0.02 mg.

2.4. Biochemical analysis

All analyses for proximate composition were performed according to the method of Association of Official Analytical Chemists (AOAC, 1990). Protein (N \times 6.25) was determined using the micro-kjeldahl procedure, crude fat by soxtec auto fat extraction system (HT6, Tecator, Sweden) using petroleum ether and crude fiber by acid–alkali digestion method in fibertec (1020 Hot Extraction, Flawil, Switzerland). Moisture was determined after oven drying at 105°C to a constant weight and ash content by incinerating in a Muffle Furnace at 500°C for 6 h. Gross energy content was determined by calculation, based on estimated 23.64 kJ/g for protein, 38.5 kJ/g for lipid and 17.15 kJ/g for carbohydrate according to Henken et al. (1986). Phytic acid was determined by the modified method of McCance et al. (1979). Tannin was determined using the

method of AOAC (1990) with slight modifications. The total oxalate was determined by the modified method of Abeza et al. (1968), and non-starch polysaccharide was analysed as total reducing sugars (Sinha et al., 2011) using the method described by AOAC (2006).

2.5. Data analysis

Data obtained from the feeding trials were analysed using a one-way analysis of variance (ANOVA) as described by Gomez and Gomez (1984). Mean differences between treatments was tested for significance ($P < 0.05$) using Duncan's Multiple Range Test (Duncan, 1955). Growth and nutrient utilization parameters were calculated according to standard formula (Castell and Tiews, 1980) as follows:

Metabolic growth rate (MGR) =

$$\frac{(W_{\text{final}} - W_{\text{initial}})}{\left\{ \left[(W_{\text{initial}}/1000)^{0.8} + (W_{\text{final}}/1000)^{0.8} \right] / 2 \right\}} \Bigg/ \text{Length of feeding trial (days)},$$

$$\text{Specific growth rate (SGR, \% / day)} = 100 \times \frac{(\ln W_{\text{final}} - \ln W_{\text{initial}})}{\text{Length of feeding trial (days)}},$$

$$\text{Feed conversion ratio (FCR)} = \frac{\text{Dry feed weight (g)}}{\text{Total wet weight gain (g)}},$$

$$\text{Protein efficiency ratio (PER)} = \frac{\text{Wet weight gain (g)}}{\text{Protein fed (g)}},$$

$$\text{Protein productive value (PPV, \%)} = 100 \times \frac{(\text{Final fish body protein} - \text{Initial fish body protein})}{\text{Crude protein fed}},$$

$$\text{Lipid productive value (LPV, \%)} = 100 \times \frac{(\text{Final fish body lipid} - \text{Initial fish lipid})}{\text{Crude lipid fed}},$$

$$\text{Energy retention value (ERV, \%)} = 100 \times \frac{(\text{Final fish body energy} - \text{Initial fish body energy})}{\text{Gross energy fed}}.$$

The condition factor (CF) of fish at the end of the experiment was calculated using the equation: $CF (\%) = 100 \times [\text{fish body weight (g)} / \text{total length (cm)}]^3$. Liver and visceral were excised from 5 fish from each replicate and weighed to determine hepatosomatic (HSI) and viscerosomatic indices (VSI) respectively using the following equations: $HSI (\%) = 100 \times [\text{Liver weight (g)} / \text{Body weight (g)}]$; $VSI (\%) = 100 \times [\text{Viscera weight (g)} / \text{Body weight (g)}]$. Based on the prevailing market price of each raw material (US\$2.08/kg for fish meal, US\$0.62/kg for autoclaved sesame seed cake, US\$0.59/kg for fermented sesame seed cake, US\$0.37/kg for wheat meal, US\$2.81/kg for fish oil, US\$3.93/kg for vitamin/mineral premix, and US\$1.12/kg for lingo bond) and the quantity that was required to make the different diets, the cost for 1 kg of each diet was calculated. Economic evaluations in terms of profit index (PI) and economic conversion ratio (ECR) of substituting fish meal with the processed sesame seed meal in the culture of Til-aqua red NMT fry were determined using the following relationships: $PI = \text{Value of fish (US\$)} / \text{Cost of feed (US\$)}$ (New, 1989); $ECR = \text{Cost of diet} \times \text{Feed conversion ratio}$ (Guo et al., 2011).

3. Results

Soaking at room temperature for 24-h period caused froth at the surface of soaked sesame seed meal. This was accompanied by lowered temperature and pH of the medium from 30.7 to 29.7°C and 6.9 to 6.0, respectively, after 24 h. The same trend was noticed during lactic acid fermentation where the pH and temperature of sesame seed meal declined from 6.10 to 5.59 and from 30.3 to 27.8°C, respectively, after 48 h.

Processing resulted in increased crude protein from 18.02% in raw sesame to 23% (autoclaved) and 24.43% (fermented). Also, fermentation and autoclaving lowered the crude fiber content of raw sesame seed meal (3.72%) by 43% and 22%, respectively. Soaking followed by either autoclaving or fermentation markedly reduced tannin content of raw sesame meal by 98% while autoclaving (0.49%) was more effective in reducing the phytic acid content of raw sesame meal (0.72%) relative to fermentation (0.6%) (Table 1).

Based on visual observation during feeding time, palatability and acceptability of the diets were good and the behavior of fish was normal in all the treatment groups except that during the first week a poor acceptance was observed for the fish fed diet 6.

The growth response, nutrient utilization and survival of Til-aqua red NMT fed the different experimental diets are presented in Table 3. Generally, there were no significant differences in the

measured growth performance parameters between the control and dietary groups. The FCR of fish that received diet 4 was significantly ($P < 0.05$) better than those of fish fed diets 2, 3 and the control but statistically similar ($P > 0.05$) to other dietary treatments. Diet 5 resulted in significantly ($P < 0.05$) higher PER relative to diets 2, 3, 6 and control. Dietary treatments did not have any significant ($P > 0.05$) effect on PPV. Fish survival ranged between 97.5% and 100% and was not affected by dietary treatments. Protein digestibility of test diets decreased with increasing inclusion level of autoclaved sesame seed meal, and was improved at 71.2 and 165.5 g/kg inclusion levels (Table 4). Lipid digestibility of diet 3 was similar to diet 6 but lower than the control and other dietary treatments. Apparent digestibility of energy was generally low; the groups that received diets 3 and 6 exhibited significantly ($P < 0.05$) lower energy digestibility compared with other treatment groups.

The carcass proximate composition at the beginning and the end of the experiment is presented in Table 5. Autoclaving and fermentation treatments did not significantly ($P > 0.05$) affect carcass crude protein, crude lipid and gross energy. The results of the economic analysis (Table 6) showed that feed cost decreased with increasing levels of sesame seed in the diets. The cost of production per kilogram fish expressed as economic conversion ratio (ECR) for diets 4 and 5 was significantly ($P < 0.05$) lower than the control and diet 3.

4. Discussion

There was an improvement in the quality of raw sesame consequent of the processing methods employed in this study. The proximate composition of raw sesame seed meal was similar to those reported in previous studies (Elleuch et al., 2007); there was however a marked variation in the crude protein content of the processed sesame meal when compared with the values reported by Guo et al. (2011) and Nang Thu et al. (2011) but similar to that reported by Mohdaly et al. (2011) for sesame cake and within the range of values of other oilseeds being used as fish meal replacers in tilapia diets (El-Saidy and Saad, 2008). The low crude protein content (23% to 24.43%) in the processed sesame meal could be attributed to the low effectiveness of the screw press used in oil extraction and thus significant lipid contents (40.0% and 38.8%) were still remained in the autoclaved and fermented meal. Ezieshi and Olomu (2007) previously reported concentration of nutrients in palm kernel meal as a result of lower amount of fat left after oil extraction. A major drawback to the use of plant-derived nutrient

Table 3
Growth performance, nutrient utilization, survival and somatic indices of Til-aqua red natural male tilapia fry fed graded levels of processed sesame seed meal.

Item	Control	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
IBW, g	1.67 ± 0.04	1.73 ± 0.10	1.67 ± 0.07	1.67 ± 0.06	1.68 ± 0.03	1.70 ± 0.07	1.70 ± 0.09
FBW, g	10.92 ± 1.17	11.81 ± 0.54	11.31 ± 1.20	10.39 ± 0.21	13.08 ± 0.44	13.38 ± 1.02	11.66 ± 1.00
SGR, %/day	3.35 ± 0.24	3.43 ± 0.18	3.41 ± 0.27	3.27 ± 0.10	3.67 ± 0.09	3.68 ± 0.21	3.44 ± 0.25
MGR, g/kg ^{0.8} per day	9.99 ± 0.65	10.31 ± 0.42	10.18 ± 0.70	9.77 ± 0.22	10.96 ± 0.22	11.02 ± 0.53	10.29 ± 0.63
FCR	1.12 ± 0.05 ^{ab}	1.05 ± 0.03 ^{abc}	1.10 ± 0.06 ^{ab}	1.14 ± 0.01 ^a	0.96 ± 0.01 ^c	0.98 ± 0.05 ^{bc}	1.09 ± 0.04 ^{abc}
PER	2.79 ± 0.12 ^{bc}	3.16 ± 0.09 ^{ab}	2.63 ± 0.14 ^c	2.77 ± 0.02 ^{bc}	3.14 ± 0.01 ^{ab}	3.40 ± 0.18 ^a	2.96 ± 0.12 ^{bc}
LER	4.58 ± 0.19 ^{ab}	6.60 ± 0.19 ^a	4.53 ± 0.24 ^{ab}	3.50 ± 0.03 ^b	5.92 ± 1.11 ^a	6.44 ± 0.83 ^a	4.78 ± 0.75 ^{ab}
PPV, %	48.34 ± 9.24	57.51 ± 1.08	38.55 ± 4.50	43.31 ± 6.77	49.19 ± 0.87	52.20 ± 2.90	52.57 ± 11.42
LPV, %	24.93 ± 1.77 ^{bc}	46.62 ± 2.55 ^a	20.23 ± 6.74 ^c	19.95 ± 4.47 ^c	38.74 ± 0.86 ^{ab}	30.06 ± 4.62 ^{bc}	29.17 ± 7.67 ^{bc}
ERV, %	26.71 ± 3.56 ^{ab}	33.39 ± 0.91 ^a	22.51 ± 0.72 ^b	23.55 ± 0.34 ^{ab}	32.51 ± 2.48 ^a	27.39 ± 1.73 ^{ab}	28.16 ± 5.41 ^{ab}
HSI, %	1.08 ± 0.07	1.05 ± 0.03	1.09 ± 0.05	1.07 ± 0.04	1.04 ± 0.00	1.06 ± 0.02	1.08 ± 0.02
VSI, %	7.38 ± 0.33 ^{ab}	6.34 ± 0.46 ^b	8.66 ± 0.21 ^a	8.59 ± 0.53 ^a	6.97 ± 0.33 ^b	6.89 ± 0.83 ^b	8.67 ± 0.00 ^a
CF	1.68 ± 0.09	1.72 ± 0.07	1.77 ± 0.03	1.70 ± 0.00	1.75 ± 0.08	1.86 ± 0.18	1.82 ± 0.06
Survival, %	99.00 ± 1.00	99.00 ± 1.00	100.00 ± 0.00	97.50 ± 2.50	99.00 ± 1.00	99.00 ± 1.00	99.00 ± 1.00

IBW = initial body weight; FBW = final body weight; SGR = specific growth rate; MGR = metabolic growth rate; FCR = feed conversion ratio; PER = protein efficiency ratio; LER = lipid efficiency ratio; PPV = protein productive value; LPV = lipid productive value; ERV = energy retention value; HSI = hepatosomatic index; VSI = viscerosomatic index; CF = condition factor.

^{a-c} Within a row, means with a same letter are not significantly different ($P > 0.05$).

Table 4

Apparent digestibility coefficients (ADC, %) for protein, lipid and energy in Til-aqua red natural male tilapia fry fed graded levels of processed sesame seed meal.

Item	Control	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
ADC _{protein}	75.07 ± 1.54 ^{ab}	81.15 ± 0.22 ^a	76.45 ± 1.75 ^{ab}	66.19 ± 3.71 ^c	77.78 ± 0.35 ^a	80.06 ± 1.23 ^a	69.07 ± 3.35 ^{bc}
ADC _{lipid}	93.47 ± 0.80 ^a	95.64 ± 3.40 ^a	96.69 ± 2.88 ^a	83.97 ± 3.40 ^b	97.06 ± 2.22 ^a	97.62 ± 1.86 ^a	91.71 ± 1.76 ^{ab}
ADC _{energy}	72.98 ± 1.58 ^a	77.80 ± 1.64 ^a	74.34 ± 2.76 ^a	62.84 ± 3.13 ^b	73.92 ± 2.96 ^a	76.59 ± 3.04 ^a	59.03 ± 2.39 ^b

ADC = apparent digestibility co-efficient.

^{a-c} Within a row, means with a same letter are not significantly different ($P > 0.05$).**Table 5**

Proximate carcass composition (% wet weight) of Til-aqua red natural male tilapia fry fed the experimental diets.

Item	Initial	Control	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Moisture, %	77.6	72.8 ± 1.30 ^{ab}	69.9 ± 1.77 ^b	76.7 ± 0.93 ^a	75.5 ± 0.81 ^{ab}	73.5 ± 0.50 ^{ab}	75.7 ± 0.65 ^a	72.3 ± 3.23 ^{ab}
Crude protein, %	11.9	16.5 ± 2.31	17.3 ± 0.07	14.2 ± 0.87	15.1 ± 2.18	15.2 ± 0.27	14.9 ± 0.12	16.9 ± 2.84
Crude lipid, %	5.4	5.4 ± 0.14	6.8 ± 0.18	4.7 ± 1.49	5.6 ± 1.04	6.6 ± 1.25	4.8 ± 0.09	5.9 ± 0.58
Ash, %	5.1	4.8 ± 0.69 ^{ab}	6.2 ± 1.69 ^a	4.4 ± 0.32 ^{ab}	3.8 ± 0.33 ^b	4.5 ± 0.43 ^{ab}	4.7 ± 0.86 ^{ab}	4.8 ± 0.18 ^{ab}
Gross energy, kJ/g	4.9	6.1 ± 0.52	6.7 ± 0.02	5.2 ± 0.37	5.7 ± 0.12	6.2 ± 0.41	5.4 ± 0.07	6.3 ± 0.89

^{a,b} Within a row, means with a same letter are not significantly different ($P > 0.05$).**Table 6**

Economic analysis of Til-aqua red natural male tilapia fry fed graded levels of differently processed sesame seed meal.

Item	Control	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
COD, US\$/kg	1.23	1.23	1.22	1.21	1.22	1.21	1.19
PI	2.91 ± 0.05 ^{ab}	3.08 ± 0.04 ^{ab}	2.96 ± 0.08 ^{ab}	2.89 ± 0.05 ^b	3.31 ± 0.01 ^{ab}	3.27 ± 0.11 ^a	3.05 ± 0.04 ^{ab}
ECR, US\$/kg	1.37 ± 0.06 ^a	1.29 ± 0.04 ^{abc}	1.34 ± 0.08 ^{ab}	1.38 ± 0.02 ^a	1.17 ± 0.01 ^c	1.19 ± 0.07 ^{bc}	1.30 ± 0.05 ^{abc}

COD = cost of diet; PI = profit index; ECR = economic conversion ratio.

^{a-c} Within a row, means with a same letter are not significantly different ($P > 0.05$).

sources has been the presence of a wide range of toxic substances which reduces their utilization by animals (Francis et al., 2001). In the present study, the most profound improvement of processing by either autoclaving or fermentation was a marked reduction in the level of tannins in processed sesame seed cake. This is highly desirable because, tannins have been reported to inhibit digestive-proteases and cause bitter astringent taste even at low levels (Francis et al., 2001). Significant reduction of tannins has been noticed in various legume seeds by various authors using similar treatments (Alegbeleye and Olude, 2009). Similarly, the observed reduction in phytic acid in this study might be a result of leaching of phytate ions into the soaking water as explained by Sokrab et al. (2012). In the present study, lactic acid fermentation slightly reduced the level of phytic acid in raw sesame meal unlike in some previous studies where similar process completely removed it (Mukhopadhyay and Ray, 1999a,b). Observation in this study could have probably resulted from thermal destruction of endogenous phytase of sesame meal when it was being prepared for fermentation as elicited by Refstie et al. (2005). Refstie et al. (2005) demonstrated that reduction in phytic acid of some grains as a result of lactic acid fermentation was due to activity of endogenous phytase of the grain but not due to microbial *Lactobacilli*; and that lactic acid fermentation did not degrade phytic acid when the soybean meals used in their study were toasted prior to fermentation. Chaudhry (1993) had earlier reported a temperature range of 35 to 45°C for optimum phytase activity. The 100°C used to prepare sesame meal for fermentation in the present study could be too high, so that endogenous phytase of sesame meal was destroyed during processing.

The good acceptance of all the experimental diets was of interest, since a low intake of feeds containing increasing levels of some vegetable feedstuffs including sesame cake have been previously reported by several authors (Dongmeza et al., 2006; Guo et al., 2011); resulting in reduced growth and poor feed

utilization. There was no significant difference in feed intake of diets incorporating autoclaved and fermented sesame seed meal relative to control diet. This agrees with the result of similar experiment previously reported in tilapia (El-Saidy and Saad, 2008) and might have been due to reduction of sesame meal anti-nutritional factors, especially tannins which are known to cause bitter astringent taste (Francis et al., 2001).

The present experiment has clearly demonstrated the potentials of sesame meal as a veritable ingredient in the diet of Til-aqua red NMT when processed by soaking followed by either autoclaving or fermentation. The enhanced growth and feed efficiency observed in the present study could be an indicator of improved nutritional quality of the processed sesame seed meal earlier elucidated.

The decrease in growth and feed utilization observed in the group fed 296.3 g/kg relative to other dietary groups mirrored the results of apparent digestibility coefficient of nutrients under current investigation and could probably be attributed to the level of non-starch polysaccharide (measured as reducing sugar, 2.23%) in the diet. Non-starch polysaccharides are constituents of a wide variety of plant derived proteins; Ghosh et al. (2005) confirmed a mixed-linked β -glucan non-starch polysaccharide in *Sesamum indicum* L. which Sinha et al. (2011) reported could be responsible for increased intestinal transit time, delayed gastric emptying and glucose absorption, increased pancreatic secretion, and slowed nutrient absorption.

Generally, nutrients are deposited in fish body at a rate proportional to their levels in diets (ImorouToko et al., 2007). The inverse relationship between moisture and lipid in the carcass of treated fish in the present investigation is in agreement with the findings of previous workers (Mukhopadhyay and Ray, 1999b; Alegbeleye et al., 2012). Carcass protein contents were higher than the initial; indicative of the fact that experimental treatments favored body protein deposition as much as the control, and confirmed an adequate protein digestibility in dietary treatments

(Alegbeleye et al., 2012). This was further revealed by the high PPV (38.55% to 57.51%) observed in the present study.

5. Conclusion

In conclusion, it could be derived that the processing (soaking in combination with either autoclaving or fermentation) employed in the present study improved the quality of sesame in terms of its nutritional and anti-nutritional compositions. Consequently, it was possible to incorporate autoclaved and fermented sesame seed meal at 71.2 and 164.3 g/kg respectively into Til-aqua red NMT diet without a deleterious effect on their growth performance, nutrient utilization and body composition. This will help to reduce cost of production and increase profitability of tilapia farming.

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