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Housefly Maggot Meal (Magmeal) as a Protein Source for *Oreochromis niloticus* (Linn.)

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Abstract

A 56 day feeding trial was conducted to evaluate the potential of housefly maggot meal (magmeal) as a protein source for tilapia (*Oreochromis niloticus*) fingerlings. Seven isoenergetic diets formulated to contain 36% protein and 20 $kJ \cdot g^{-1}$ gross energy (dry matter basis), were prepared by replacing fish meal with magmeal. Fifteen fingerlings (average initial weight 2.0±0.1g) stocked in each experimental tank were fed in triplicates at 5% of their body weight in two portions per day (a level previously established). Growth and food conversion ratio were adequate and comparable without any significant differences ($P<0.5$) between feeding groups. Result of nutrient composition analysis showed that magmeal contains a good profile of amino acid compared to fish meal, but has a high content of crude fat (19.8%) which influenced the fat content and fatty acid composition of diets and fish. Feeding *Oreochromis niloticus* fingerlings with feeds containing magmeal can give growth, equivalent to that obtained with fishmeal as the main protein source. However, it is recommended that adequate sources of n – 6 and n – 3 fatty acids are included in diets of magmeal to enhance the optimal fatty acid profile necessary for metabolic functions.

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Introduction

The high prices of fishmeal in world markets have necessitated the search for substitute protein sources. Fishmeal has been replaced with cheap plant proteins (Jackson et al. 1982; Tacon & Jackson 1985; Webster et al. 1992; Ogunji & Wirth 2001) but not all attempts have been successful because of deficiency in essential amino acids and effects of anti-nutrition factors. Growth of fish especially in early juvenile is often better when feeds contain animal protein, rather than of plant origin. Insects may be a valuable animal protein source (Dieredied 1993) and various developmental stages of insects have been used to feed fish and farm animals (Bondari & Sheppard 1981).

Houseflies *Musca domestica* L. larvae utilise decaying organic waste such as manure, vegetables and exposed food materials to produce animal protein and the larvae can be used to produce a meal (magmeal). There are reports on the use of magmeal in poultry feeds (Teotia & Miller 1973; Atteh & Adedoyin 1993; Atteh & Ologbenla 1993; Salami 1999; Akpodiete & Inoni 2000; Awoniyi et al. 2003), but there are few reports on studies with fish (Spinelli et al. 1979; Adesulu & Mustapha 2000; Fasakin et al. 2003). In terms of economic advantage, Ajani et al. (2004) reported that the replacement of fish meal with 50 and 100% magmeal will lead to a reduction in the cost of fish production by 18 and 28%. It is assumed that the utilization of magmeal offers a good opportunity for the development of low cost fish feeds, especially in the tropics and subtropics where maggots can easily be harvested throughout the year without much cost. This study is aimed at assessing the potential of housefly maggot meal (magmeal) as a protein source for tilapia *Oreochromis niloticus* L. The influence of varying dietary contents of magmeal on growth and fatty acid composition was examined.

Methods

Housefly maggots produced in Nigeria on poultry droppings were used to produce magmeal as described by Ajani et al. (2004) and Adesulu & Mustapha (2000). Seven test feeds with nominal 36% protein content were formulated with fishmeal and magmeal as the main protein sources (Table 1). All ingredients were thoroughly mixed with sunflower oil, water was added for dough and the feed was then pressed through a sieve to give pellets of 1 mm diameter. After drying at room temperature the feeds were stored at – 2°C until used.

Table 1. Composition of experimental diets (%)

Ingredients	Experimental Diets						
	1 (Control)	2	3	4	5	6	7
Fish Meal (FM)	43	34	28	22	16	10.5	-
Magmeal	-	15	25	35	45	55	68
Soy Meal (SM)	12	12	12	12	12	12	16
Sunflower Oil	5	5	5	5	5	5	5
Vita/Min Mix[1]	4	4	4	4	4	4	4
Potato Starch	36	30	26	22	18	13.5	7

[1]Vitamin and Mineral mix (Spezialfutter Neuruppin - VM BM 55/13 Nr. 7318) supplied per 100g of dry feed : Vitamin A 12000 I.E; Vitamin D3 1600 I.E; Vitamin E 160mg; Vitamin K3 6.4mg; Vitamin B1 12mg; Vitamin B2 16mg; Vitamin B6 12mg Vitamin B12 26.4µg; Nicotinic acid 120mg; Biotin 800µg; Folic acid 4.8mg; Pantothenic acid 40mg, Inositol 240mg; Vitamin C 160mg; Antioxidants (BHT) 120mg; Iron 100mg; Zink 24mg; Manganese 16mg; Cobalt 0.8mg; Iodine 1.6mg; Selenium 0.08mg

Fifteen tilapia fingerlings (initial mean weight 2.0±0.1g) bred at the Institute of Freshwater Ecology and Inland Fisheries Berlin Germany were stocked into tanks (28 x 28 x 51.5 cm) within a recirculation system with triplicate tanks for each feed treatment. The fish were manually fed at 5% of their body weight in two portions per day at 9.00 and 15.00 hrs for 56 days (Ogunji & Wirth 2000). Fish were weighed every two weeks and the quantity of food was adjusted accordingly. Tanks were cleaned three times a week and water conductivity, pH, oxygen concentration and temperature were measured regularly. Oxygen saturation was kept above 60% and temperature was maintained at 26±1°C.

At the start of the experiment, 20 fish were sacrificed, homogenised and kept frozen until analysed for whole body composition. At the end of the experiment all fish were killed and individually weighed, then 21 from each feeding group (seven per replicate) were randomly selected and homogenised. Homogenised fish samples were freeze dried at a temperature of –54°C as were samples of ingredients and feed. All samples were analysed for proximate composition in duplicate. Protein (N x 6.25) was analysed using a Kjeltec System (Tecator) and crude fat using a Soxtec System HT (Tecator) with petroleum ether as the solvent. Ash was determined by burning in a muffle furnace at 550°C for 10 hours. Gross energy was calculated using the following factors: crude protein = 23.9 $kJ \cdot g^{-1}$, crude lipids = 39.8 $kJ \cdot g^{-1}$ and nitrogen free extract (NFE) = 17.6 $kJ \cdot g^{-1}$ (Schulz et al. 2005). Amino acids were analysed as described by Buchholz (1997) and

Ogunji & Wirth (2001) with minor modifications that allowed for effective measurement using Merck/Hitachi HPLC equipment (AS-400 Intelligent Autosampler, L-6200 Intelligent Pump, F-1080 Fluorescence Detector, L-5025 Column Thermostat and D-6000 HPLC Manager) and a Nova-Pak C-18 4 µm 3.9 mm x 300 mm Column (Waters). The system was calibrated using amino acid standards (SIGMA Product No. A9906). Fatty acid composition of fish samples and feed ingredients were analyzed using gas-liquid chromatography as described by Schulz et al. (2005) using triclosan acid as the internal standard.

Specific growth rate (SGR) and food conversion ratio (FCR) were calculated as follows:

FCR = weight of food given/live weight gain

SGR = (ln W2 - ln W1/T2-T1) x 100, where W2 = final weight of fish, W1 = initial weight of fish and T2 –T1 = growth period (days)

Survival % = $F_2/F_1 \times 100$, where F_1 = number of fish at the beginning of experiment, F_2 = number of fish at the end of the experiment.

All calculations were based on each of the triplicate tank per treatment. All growth data were subjected to one-way analysis of variance (ANOVA). The significance of difference between means was determined by Duncan's multiple range test (P<0.05) using SPSS for Windows (Version 12). Values are expressed as means ± SE.

Results

Proximate and amino acid composition of fish meal and magmeal used in this study are presented in table 2. The high content of crude fat in magmeal affected the fat but not the energy content of experimental diets with fat contents increasing with greater inclusion of magmeal (Table 3). The high crude protein content in fish meal and low concentration in magmeal influenced dietary protein content (34–38%). All the experimental diets contained relatively similar amino acid profile (Table 3).

Growth data and food conversion ratio of *O. niloticus* fingerlings fed with experimental diets for 56 days are presented in table 4. Growth of *O. niloticus* fingerlings was equivalent in all feeding groups. The whole body composition of fish at the beginning and end of the experiment is given in table 5. Percentage body protein ranged from 16.02 to 16.85%

with no significant difference. The fish fed with diet 7 had the highest percentage of fat, NFE and the lowest percentage of moisture.

Table 2. Comparison of amino acid and nutrient composition (% dry matter) of fish meal and magmeal used in this study[1].

Components	Fish Meal	Magmeal
Dry Matter	91.0	96.4
Crude Protein	70.7	37.5
Crude Fat	7.8	19.8
Ash	18.3	23.1
NFE[2]	3.21	19.6
Gross energy ($kJ\bullet g^{-1}$)[3]	20.6	20.3
Amino Acids		
Aspartic acid	3.74	1.69
Glutamic acid	2.69	2.53
Serine	1.92	1.47
Histidine*	1.76	1.90
Glycine	0.94	0.35
Threonine*	2.53	2.83
Arginine*	3.34	1.74
Alanine	3.60	1.64
Tyrosine	0.71	0.95
Tryptophan*	1.91	0.58
Methionine*	1.29	1.66
Valine*	0.95	0.50
Phenylalanine*	2.90	3.83
Isoleucine*	0.99	0.63
Leucine*	2.74	2.11
Lysine*	3.96	1.66

*Essential Amino Acids. [1]Values are mean of duplicate determinations ± SE.
[2]Nitrogen free extract + fibre, (NFE) = 100 - (% protein + % fat + % ash).
[3]Calculated by: crude protein = 23.9 $kJ\bullet g^{-1}$; crude lipids = 39.8 $kJ\bullet g^{-1}$; NFE = 17.6 $kJ\bullet g^{-1}$ (Schulz et al. 2005).

Crude fat and fatty acid composition of feed ingredients, diets and whole fish are shown in tables 6 to 8. Magmeal contains higher levels of linoleic acid (18:2 n – 6), linolenic acid (18:3 n – 3) and 18:4 n – 3 in the triglycerides (TG) and phospholipids (PL) fractions than fishmeal. Fish-meal on the other hand, contained a very high content of docosahexaenoic acid (DHA, 22:6 n – 3) (Table 4). This influenced the total content of n – 3 i.e. polyunsaturated fatty acids (PUFA) which decreased with increasing concentration of magmeal in test feeds. The n – 3/n – 6 ratio in TG of magmeal was 0.8 while fishmeal was 3.5. The total saturated and monoene fatty acids (TG) in diets as well as fish, increased with increased magmeal inclusion.

Table 3. Proximate composition and amino acid profile (% dry matter) of experimental diets[1]

Component	Experimental diets						
	1 (Control)	2	3	4	5	6	7
Dry Matter	92.4	93.4	93.6	94.2	94.5	94.8	95.6
Crude Protein	38.1	37.2	37.0	36.0	35.6	35.0	34.0
Crude Fat	10.0	12.3	13.1	14.2	17.0	17.2	17.4
Ash	12.03	13.57	14.78	15.89	16.88	18.44	20.27
NFE[2]	39.9	36.93	35.12	33.91	30.52	29.36	28.33
Gross energy ($kJ \cdot g^{-1}$)[3]	20.11	20.29	20.24	20.22	20.65	20.38	20.04
Amino Acids:							
Aspartic Acid	2.75	2.78	2.77	2.03	2.47	2.39	2.48
Glutamic Acid	3.08	1.65	2.03	3.54	2.56	2.36	2.42
Serine	1.30	1.31	1.27	1.23	1.19	1.23	1.20
Histidine*	1.01	1.25	1.30	1.35	1.59	1.83	1.86
Glycine	0.45	0.44	0.41	0.42	0.36	0.36	0.33
Threonine*	1.55	1.52	1.47	1.46	1.30	1.33	1.28
Arginine*	2.24	2.19	2.10	2.09	1.84	1.87	1.84
Taurine	0.40	0.34	0.28	0.24	0.16	0.12	0.02
Alanine	2.31	2.28	2.25	2.26	2.04	2.07	1.94
Tyrosine	0.52	0.59	0.63	0.68	0.68	0.75	0.82
Methionine (+Cys)*	1.89	1.70	1.70	1.72	1.64	1.61	1.62
Valine*	0.65	0.63	0.61	0.62	0.57	0.58	0.58
Phenylalanine*	2.83	2.97	2.93	3.45	2.75	2.75	2.86
Isoleucine*	0.82	0.76	0.75	0.76	0.70	0.69	0.69
Leucine*	2.87	2.49	2.65	2.42	2.27	2.22	2.22
Lysine*	2.48	2.34	2.21	2.15	1.93	1.89	1.70

*Essential Amino Acids. [1]Values are mean of duplicate determinations ± SE.
[2]Nitrogen free extract + fibre, (NFE) = 100 - (% protein + % fat + % ash).
[3]Calculated by: crude protein = 23.9 $kJ \cdot g^{-1}$; crude lipids = 39.8 $kJ \cdot g^{-1}$; NFE = 17.6 $kJ \cdot g^{-1}$ (Schulz et al. 2005).

Discussion

The results of this study have shown that growth of *Oreochromis niloticus* fingerlings fed with feeds containing magmeal was equivalent to that obtained with fishmeal as the main protein source. This agrees with the results obtained by Fashina-Bombata & Balogun (1997), Adesulu & Mustapha (2000) and Ajani et al. (2004).

Table 4. Growth data and food conversion ratio of *O. niloticus* fingerlings fed experimental diets*

Parameters	Experimental diets						
	1 (Control)	2	3	4	5	6	7
Initial weight (g)	2.08±0.1^{a}	2.09±0.1^{a}	2.09±0.1^{a}	2.01±0.17^{a}	1.93±0.2^{a}	1.94±0.11^{a}	1.91±0.10^{a}
Final weight (g)	14.46±1.3^{a}	15.39±2.3^{a}	17.17±0.5^{a}	15.97±2.1^{a}	16.00±2.0^{a}	14.37±0.1^{a}	13.16±0.1^{a}
Total feed intake (g)	13.95±0.8^{a}	14.53±1.6^{a}	15.83±0.8^{a}	15.23±1.7^{a}	14.90±1.6^{a}	14.24±0.6^{a}	13.73±0.5^{a}
SGR	3.45±0.7^{a}	3.53±0.21^{a}	3.76±0.1^{a}	3.68±0.1^{a}	3.76±0.1^{a}	3.58±0.1^{a}	3.45±0.1^{a}
FCR	1.14±0.1^{a}	1.12±0.10^{a}	1.05±0.0^{a}	1.10±0.0^{a}	1.06±0.0^{a}	1.15±0.1^{a}	1.22±0.1^{a}
Survival %	95.6±4.4^{a}	100±0.0^{a}	93.3±6.7^{a}	91.1±4.4^{a}	76.8±3.3^{b}	91.1±2.2^{a}	73.3±6.6^{b}

*Values represent mean ± SE of each replicate per treatment. Values in the same row with different superscript letters are significantly different (P < 0.05) from each other.

Table 5. Whole body composition of fish (% fresh weight basis) at the beginning and end of experiments*

	Moisture	Crude Protein	Crude Fat	Ash	NFE
Initial Status	78.11±0.1	14.04±0.0	2.16±0.0	5.10±0.1	0.59±0 .0
Diets					
l (Control)	72.60±0.1$^{ab c}$	16.85±0.27^{a}	4.96±0.27^{a}	4.80±0.03^{a}	0.79±0.05^{a}
2	73.47±0.4^{a}	16.85±0.35^{a}	4.91±0.02^{a}	3.88±0.01^{b}	0.89±0.09^{ab}
3	71.86±0.3^{cd}	16.48±0.44^{a}	6.28±0.02^{b}	3.63±0.06^{c}	1.75±0.26^{c}
4	72.87±0.2^{ab}	16.49±0.07^{a}	6.15±0.04^{b}	3.42±0.02^{d}	1.08±0.24^{ab}
5	72.09±0.1^{bcd}	16.36±0.13^{a}	7.13±0.07^{c}	3.34±0.03^{d}	1.09±0.06^{ab}
6	72.74±0.2$^{ab c}$	16.02±0.25^{a}	7.03±0.05^{c}	3.08±0.03^{e}	1.13±0.11^{ab}
7	71.33±0.38^{d}	16.53±0.15^{a}	7.64±0.14^{d}	3.12±0.03^{e}	1.39±0.04$^{b c}$

*Values are mean of determinations ± SE. Values on same column with different superscripts are significantly (P<0.05) different.

Table 6. Selected fatty acid composition (%) in triglyceride (TG) and phospholipids (PL) of magmeal, fishmeal and soy meal used in feed formulation*

Fatty acids	Magmeal		Fishmeal		Soy-meal	
	TG	PL	TG	PL	TG	PL
8:0	36.2	2.1	trace	Trace	trace	trace
16:0	12.1	15.7	16.6	21.7	10.9	18.1
16:1 n-7	6.1	7.7	9.5	2.6	0.1	0.1
18:0	2.1	5.7	3.2	5.1	2.4	4.3
18:1 n-9	3.5	32.2	7.6	7.5	27.0	11.2
18:2 n-6	3.5	9.3	0.9	1.0	49.1	57.4
18:3 n-3	1.2	0.2	0.2	0.2	7.0	6.0
18:4 n-3	2.4	0.6	0.5	0.2	--	--
20:1 n-9	0.2	2.5	0.1	0.1	trace	trace
20:4 n-6	0.1	0.3	0.1	0.5	trace	trace
20:4 n-3	0.1	0.2	0.2	0.3	--	--
20:5 n-3	0.2	0.2	1.1	1.7	--	--
22:1 n-11	trace	2.8	18.6	11.2	--	--
22:2 n-6	0.1	0.1	0.1	0.1	trace	trace
22:3 n-6	0.7	0.1	0.1	0.2	trace	trace
22:5 n-3	trace	0.2	1.9	2.6	trace	trace
22:6 n-3	trace	0.1	8.1	32.8	trace	trace
Σn-6[1]	5.1	10.5	3.5	3.2	49.7	57.7
Σn-3[2]	4.0	2	12.1	37.8	7.0	6.0
Σ n-3/Σ n-6	0.8	0.2	3.5	11.8	0.1	1.0
Σ Saturated[3]	64.6	29.1	22.8	29.6	13.8	22.8
Σ Monoene[4]	12.7	52.3	45.3	26.2	27.3	11.5
Σ PUFA[5]	9.1	12.5	15.6	41.0	56.7	63.7

*Values represent mean of duplicate determinations and indicate percentage (%) of total detectable fatty acids. [1]Contains 18:2 n-6, 18:3 n-6, 20:2 n-6, 20:3 n-6, 20:4 n-6, 22:2 n-6, 22:3 n-6, 22:4 n-6, and 22:5 n-6; [2]Contains 18:3 n-3, 18:4 n-3, 20:3 n-3, 20:4 n-3, 20:5 n-3, 21:5 n-3, 22:5 n-3 and 22:6 n-3; [3]Contains 8:0, 9:0, 10:0, 12:0, 13.0, 14:0, 15:0, 16:0, 17:0, 18:0, 19:0, 20:0, 21:0, 22:0, 23:0, and 24:0; [4]Contains 12:1, 14:1 n-7, 14:1 n-5, 15:1, 16:1 n-9, 16:1 n-7, 16:1 n-5, 17:1, 18:1 n-9, 18:1 n-7, 20:1 n-11, 20:1 n-9, 22:1 n-11, 22:1 n-9, 24:1 n-9; [5]Contains 18:2 n-6, 18:3 n-3, 18:3 n-6, 18:4 n-3, 20:2 n-6, 20:3 n-3,20:3 n-6, 20:4 n-3, 20:4 n-6, 20:5 n-3, 21:5 n-3, 22:2 n-6, 22:3 n-6, 22:4 n-6, 22:5 n-3, 22:6 n-3 and 22:5 n-6

One point in favour of magmeal over many other alternative protein sources especially those of plant origin may be its balanced amino acid profile (Table 2), there seem to be no evidence that any amino acids is severely limiting (Spinelli et al. 1979). Several other ingredients of animal origin (e.g. feather meal, poultry by-product meal and meat with bone meal) may not have been completely successful as fish meal substitutes due to their inferior amino acid profile compared to fishmeal (Abdelghany 2003). Magmeal is also rich in phosphorus, trace elements and B complex vitamins (Teotia & Miller 1973).

Table 7. Selected total fatty acid composition (%) of experimental diets

Fatty Acids	Experimental diets						
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7
12:0	0.1	0.1	0.1	0.2	0.2	0.3	0.3
14:0	2.4	4.8	6.7	7.6	7.7	9.8	8.9
15:0	0.1	0.3	0.4	0.8	0.7	1.2	1.3
16:0	11.3	12.7	13.3	13.7	15.2	15.0	15.4
16:1 n-7	2.9	3.9	5.2	5.0	5.3	6.4	6.9
18:0	4.21	4.8	4.7	4.6	6.0	4.2	4.7
18:1 n-9	21.1	23.9	24.3	25.3	26.2	26.3	27.9
18:2 n-6	35.8	33.5	30.6	30.4	24.5	25.9	25.5
18:3 n-3	0.9	0.8	0.7	0.7	0.5	0.6	0.6
18:4 n-3	0.8	0.6	0.5	0.8	0.7	0.6	0.7
20:1 n-11	0.5	0.3	0.4	0.4	0.4	0.6	1.2
20:4 n-6	0.5	0.4	0.3	0.4	0.3	0.3	0.3
20:5 n-3	6.0	3.9	2.7	2.3	1.5	1.0	0.3
22:1 n-11	0.4	0.3	0.3	0.2	0.8	0.1	0.6
22:1 n-9	0.1	0.2	0.2	0.0	0.3	0.1	0.0
22:2 n-6	0.2	0.2	0.1	0.1	0.2	0.2	0.2
22:3 n-6	trace	0.0	0.0	0.0	0.1	0.1	0.0
22:4 n-6	0.1	0.1	0.2	0.1	0.2	0.1	0.2
22:5 n-6	trace	0.0	0.0	0.0	0.0	0.0	0.0
22:5 n-3	1.0	0.6	0.5	0.4	0.3	0.2	0.1
22:6 n-3	7.1	4.5	3.3	2.5	2.1	1.3	0.1
24:1 n-9	037	0.2	0.2	0.08	0.1	0.1	0.1
Σn-6[1]	36.9	34.5	32.7	31.5	27.5	27.8	27.3
Σn-3[2]	15.9	10.5	7.8	6.8	5.3	3.7	1.8
Σ n-3/Σ n-6	0.4	0.3	0.3	0.2	0.2	0.1	0.1
Σ Saturated[3]	20.4	24.1	26.5	28.7	31.3	32.6	31.7
Σ Monoene[4]	26.5	30.4	32.5	32.6	35.0	35.5	38.4
Σ PUFA[5]	52.8	45.0	40.5	38.2	32.8	31.5	29.1

*Values represent mean of duplicate determinations and indicate percentage (%) of total detectable fatty acids. [1]Contains 18:2 n-6, 18:3 n-6, 20:2 n-6, 20:3 n-6, 20:4 n-6, 22:2 n-6, 22:3 n-6, 22:4 n-6, and 22:5 n-6; [2]Contains 18:3 n-3, 18:4 n-3, 20:3 n-3, 20:4 n-3, 20:5 n-3, 21:5 n-3, 22:5 n-3 and 22:6 n-3; [3]Contains 8:0, 9:0, 10:0, 12:0, 13.0, 14:0, 15:0, 16:0, 17:0, 18:0, 19:0, 20:0, 21:0, 22:0, 23:0, and 24:0; [4]Contains 12:1, 14:1 n-7, 14:1 n-5, 15:1, 16:1 n-9, 16:1 n-7, 16:1 n-5, 17:1, 18:1 n-9, 18:1 n-7, 20:1 n-11, 20:1 n-9, 22:1 n-11, 22:1 n-9, 24:1 n-9; [5]Contains 18:2 n-6, 18:3 n-3, 18:3 n-6, 18:4 n-3, 20:2 n-6, 20:3 n-3,20:3 n-6, 20:4 n-3, 20:4 n-6, 20:5 n-3, 21:5 n-3, 22:2 n-6, 22:3 n-6, 22:4 n-6, 22:5 n-3, 22:6 n-3 and 22:5 n-6

The dietary crude protein content decreased from 38% in Diet 1 to 34% in Diet 7 while dietary fat contents increased from 10.0 to 17.4% with an increase in the dietary proportion of magmeal. No significant effect on fish growth was observed (Table 4). De Silva et al. (1989) observed no significant difference in growth rate when tilapias were given feeds containing protein within the dietary range of 35 to 45%. At the end of this study increased whole body protein content was observed in all experimental fish groups (Table 5), similar to the results reported by Ajani et al. (2004) for the same species. On the other hand, the dietary fat contents (10.0 – 17.4%) were within the levels tolerable to *O. niloticus*. De Silva et al. (1989) used a similar level (12.00 – 15.20% lipid and 19.40 – 20.60 kJ•g^{-1} energy) for the same species. Increasing the lipid content in fish diet increased the possibility that dietary protein would not be used for energy, but for growth and tissue production (Xu et al. 2001).

Table 8. Selected fatty acid composition (%) of triglycerides (TG) in fish*

Fatty acid	Initial Status	Fish fed with						
		Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7
12:0	0.2	0.1	7.0	10.9	12.8	15.7	14.8	13.2
14:0	6.4	2.7	5.6	8.0	8.4	9.9	10.4	11.3
16:0	15.7	12.5	12.0	13.2	12.4	11.7	12.5	13.5
16:1 n-7	5.8	3.5	20.9	3.8	4.3	4.6	4.6	5.0
18:0	2.9	4.2	3.5	3.7	3.2	2.9	3.0	3.3
18:1 n-9	14.7	21.6	19.6	18.5	20.1	21.6	20.2	23.5
18:1 n-7	3.0	2.8	2.6	2.7	2.2	trace	2.4	trace
18:2 n-6	4.2	30.9	26.5	22.4	21.5	20.4	18.7	16.6
18:3 n-6	0.1	0.4	0.4	0.4	0.4	0.4	0.4	0.5
18:3 n-3	0.3	0.2	0.1	0.1	0.1	0.1	0.1	trace
18:4 n-3	trace	0.6	0.2	0.1	trace	trace	trace	trace
20:1 n-11	trace	0.3	0.5	0.7	1.0	1.3	1.3	1.2
20:3 n-6	0.1	1.4	0.9	0.9	1.0	1.0	1.1	1.4
20:4 n-6	0.4	1.0	1.0	1.0	1.0	1.1	1.2	1.4
20:4 n-3	0.4	0.5	0.7	0.7	0.6	0.7	0.6	0.7
20:5 n-3	0.4	0.4	0.4	0.8	0.4	0.6	0.5	0.5
22:1 n-11	1.3	0.9	0.6	0.3	0.2	0.2	0.1	0.1
22:1 n-9	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1
22:2 n-6	0.1	0.1	0.5	0.1	0.1	0.1	0.2	0.3
22:3 n-6	0.1	0.3	0.2	0.2	0.1	trace	0.1	0.1
22:4 n-6	0.2	0.3	0.5	0.3	0.4	0.4	0.4	0.5
22:5 n-6	0.2	0.2	0.2	0.1	0.3	0.3	0.4	0.6
22:5 n-3	4.3	3.8	2.6	1.8	1.3	0.8	0.5	0.3
22:6 n-3	9.2	6.3	4.4	3.2	2.5	1.6	1.1	0.5
Σn-6[1]	5.7	34.6	30.3	25.6	24.9	23.7	22.6	21.5
Σn-3[2]	14.7	11.8	8.3	6.6	4.8	3.7	2.8	2.0
Σ n-3/Σ n-6	2.6	0.3	0.3	0.3	0.2	0.2	0.1	0.1
Σ Saturated[3]	26.7	20.5	29.5	36.9	38.0	41.3	42.2	42.7
Σ Monoene[4]	25.8	29.9	45.9	27.8	29.7	29.3	30.4	31.6
Σ PUFA[5]	20.4	46.6	38.6	32.2	29.7	27.4	25.4	23.5

*Values represent mean of duplicate determinations and indicate percentage (%) of total detectable fatty acids of 21 fish. [1]Contains 18:2 n-6, 18:3 n-6, 20:2 n-6, 20:3 n-6, 20:4 n-6, 22:2 n-6, 22:3 n-6, 22:4 n-6, and 22:5 n-6; [2]Contains 18:3 n-3, 18:4 n-3, 20:3 n-3, 20:4 n-3, 20:5 n-3, 21:5 n-3, 22:5 n-3 and 22:6 n-3; [3]Contains 8:0, 9:0, 10:0, 12:0, 13.0, 14:0, 15:0, 16:0, 17:0, 18:0, 19:0, 20:0, 21:0, 22:0, 23:0, and 24:0; [4]Contains 12:1, 14:1 n-7, 14:1 n-5, 15:1, 16:1 n-9, 16:1 n-7, 16:1 n-5, 17:1, 18:1 n-9, 18:1 n-7, 20:1 n-11, 20:1 n-9, 22:1 n-11, 22:1 n-9, 24:1 n-9; [5]Contains 18:2 n-6, 18:3 n-3, 18:3 n-6, 18:4 n-3, 20:2 n-6, 20:3 n-3,20:3 n-6, 20:4 n-3, 20:4 n-6, 20:5 n-3, 21:5 n-3, 22:2 n-6, 22:3 n-6, 22:4 n-6, 22:5 n-3, 22:6 n-3 and 22:5 n-6

The dietary n – 6 PUFA content, Σ n-3 / Σ n-6 ratio as well as the docosahexaenoic acid (DHA) compositions of the whole fish decreased with increased fat content. In contrast, total saturated fatty acid in fish body increased with increased fat content. The low body concentration of DHA and high concentration of eicosapentaenoic acid (EPA) mirrored the dietary EPA and DHA profiles. According to Stickney & Hardy (1989) the requirement for n – 3 fatty acids in tilapias is known to be considerably lower than the other warm water fish, and they also do not have a specific requirement for 18:3n – 3. The overall n -3 fatty acid requirement can be met from high molecular fatty acids such as 20:5n – 3 and 22:6n – 3. However, absolute amounts of n -3 PUFA in body lipids can be enhanced by increasing amounts of the same fatty acids in the diets (Silver et al. 1993). As such there may be a need to include some quantities of fish oil in magmeal feeds considering the high metabolic functions of PUFA n-3 series. Since magmeal contains high fat content, this can be applicable only when magmeal is defatted. Fasakin et al. (2003) reported a better growth performance when African cat fish *Clarias gariepinus* is fed with diets containing defatted maggot meals than full fat magmeal.

The fish fed with diet 7 had the highest percentage of fat, NFE and lowest percentage of ash. Cowey (1993), in reviewing some effects of nutrition on flesh quality, pointed out that changes in flesh composition are related mainly to moisture and lipid content, and that an increase in ration size or lipid content leads to an increase in flesh lipids with a proportional reduction in moisture content. A similar trend was also observed in the whole body of sea bass (Morales & Teles 1995), and whole body fat content of rainbow trout (Reinitz & Hizel 1980; Refstie & Austreng 1981) when dietary fat content was increased at the expense of carbohydrate.

Fish survival was above 90% in most feeding groups except in diets 5 and 7. It is not certain if the cause of mortality can be directly linked to magmeal inclusion in experimental feed especially when viewed from the perspective of growth performance and fish survival % with diet 6 (91%) with high magmeal concentration (Table 4).

The observations reported in this paper suggest that magmeal has a good amino acid profile. Feeding *Oreochromis niloticus* fingerlings with feeds containing magmeal can give growth, equivalent to that was obtained with fishmeal as the main protein source. However, it is recommended that adequate sources of n – 6 and n – 3 fatty acids are included in diets of magmeal to enhance the optimal fatty acid profile necessary for metabolic functions. In this study, soybean complemented the n – 6 fatty acid concentrations of diets. Expected results may be realised when defatted magmeal is used. More studies are however, needed to examine the performance of other fish species with magmeal and the effect of this ingredient on various physiological activities and stages of fish development.

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