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Apparent Digestibility Coefficient of Housefly Maggot Meal (magmeal) for Nile Tilapia (*Oreochromis niloticus* L.) and Carp (*Cyprinus carpio)*

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Abstract

To evaluate the digestibility of house fly maggot meal (magmeal) formulated reference diet (containing fishmeal as primary protein source) and a test diet (containing 70% reference diet + 30% maggot meal) were fed to triplicate groups of tilapia and carp with initial average body weights of 108.3±32 and 110.3±23 g, respectively. Faeces were collected over a period of 15 days by siphoning. The apparent digestibility coefficients (ADCs) of magmeal calculated for tilapia (dry matter: 47.65%, crude protein: 57.7%, crude fat: 86.1%; gross energy: 58.1%) were significantly lower than that for carp (dry matter: 63.84%, crude protein: 84.9%, crude fat: 96.8%, energy: 74.9%). Spawning activities of experimental tilapia and soft faeces consistency of carp may have affected the results.

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Introduction

Several feed ingredients including animal and plant protein sources, have been investigated to find substitutes for fish meal in fish diets (El-Sayed 1999). Though these feed ingredients may be cheaper than fishmeal, diverse responses on growth parameters have been reported. The reasons for the variations are summarized by Ogunji (2004) and include the protein composition and amino acid profile, palatability/acceptability, phosphorus content and availability, anti-nutritional factors (especially in plant protein sources) and apparent digestibility of alternative feeds.

Digestibility is the quantification of digestive process. It gives the relative measure of the extent to which ingested food and its nutrient components have been digested and absorbed by animals (De Silva and Anderson 1995). From its chemical composition a feed ingredient may appear to be an excellent source of nutrients but unless it can be digested and absorbed by the target species the actual value can be limited. Therefore, information on the nutrient digestibility of the various feed ingredients used in formulating fish feeds is crucial for an effective substitution of one ingredient for another (Köprücü and Özdemir 2005).

Interests in the study of the use of housefly maggot meal (magmeal) as substitute for fishmeal in fish diets, have increased in recent times (Spinelli et al. 1979; Adesulu and Mustapha 2000; Fasakin et al. 2003; Ajani et al. 2004). However, no report has been published so far on the digestibility of this alternative protein source. This study was therefore designed to determine the apparent digestibility coefficient of housefly maggot meal (magmeal) for Nile tilapia (*Oreochromis niloticus*) and carp (*Cyprinus carpio).*

Materials and Methods

Culture system

Experimental fish were reared in two recirculation systems each comprising of nine tanks and a filtration unit with a sedimentation chamber for settlement of particulate matter and a trickling filter filled with plastic tubes for biological purification. Mean and standard deviation (±) of water temperature, pH, O_2-content and conductivity (measured with WTW multi

340 I, Weilheim, Germany) during the experiment were similar in both recirculation systems: 25.84 °C (± 0.29, System A), 25.95°C (± 0.25, System B); 7.94 (± 0.08), 7,95 (± 0.15); 6.9 mg l^{-1} (± 0.23), 6.73 (± 0.28) and 826 µsm cm^{-1} (± 5.7), 822 µs cm^{-1} (± 5.2).

Dietary formulation

Composition of reference and test diets is shown in table 1. The reference diet was formulated according to Bureau and Cho (1994). Chromic oxide (Cr_2O_3) was used as inert marker at a concentration of 1% in the reference diet. The test diet was formulated using 70% of the reference diet with 30% of test ingredient (magmeal). Housefly maggots produced in Nigeria on poultry droppings were used to produce magmeal as described by Ajani et al. (2004) and Adesulu and Mustapha (2000). All dry diet components, including the vitamin and mineral mixture, were thoroughly mixed with oil. Water was added and the feed pressed into pellets of 1 mm diameter. The wet pellets were dried for 3 days at room temperature and stored at -2°C until used. The reference and test diets were assigned to tilapia and carps in triplicate tanks respectively. The fish were fed to apparent satiation at a level of 3% of their body weight in two portions at 08.00 and 15.00 h•day^{-1} respectively. This feeding level was reduced to 2% of body weight•day^{-1} for tilapia after 7 days to ensure complete consumption of food.

Table 1. Composition of reference and test diets (%) dry matter (DM)

Ingredients	Reference diet	Test diets
Fish Meal	30	
Soy meal	17	-
Wheat Gluten	13	-
Wheat Flour	28	-
Fish Oil	3	-
Canola Oil	3	-
Vita/Min Mix[1]	1	-
Silicate gel	4	-
Chromic oxide (Cr_2O_3)	1	-
Reference diet		70
Test ingredient (magmeal)		30
Total	100	100

[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.

Feeding trials and analysis

Thirty tilapia with an initial average body weight of 108.3±32 g and 36 carp with an initial average body weight of 110.3±23 g were randomly distributed in six tanks with a volume of 240 L each of the similar recirculation systems at a stocking density of 5 (tilapia) and 6 (carp) individuals per tank. They were acclimated to the diets for 10 days before faecal collections commenced. Faeces were collected over a 15 day period by siphoning (Tantikitti and Chimsung 2001; Pavasovic et al. 2006) 30 minutes after feeding for the tilapia and 2 hours for carps, the time carps commence emptying their bowls after feeding. Food particles were however removed from the tanks before siphoning, and faeces collection lasted for only 30 minutes to avoid leaching out of nutrients from the faeces. Pavasovic et al. (2006) observed no significant loss of detectable chromium (Cr) in faecal samples of claw crayfish (*Cherax quadricarinatus*) immersed in water for one hour. At the end of the experiment, faeces collected per tank and stored at -2°C were centrifuged at 5000× g for 15 min and supernatant was discarded (Köprücü and Özdemir 2005) before freeze drying along side the diet samples started.

Chemical analysis and calculations

Freeze-dried samples of experimental diets, magmeal and fish faeces were analyzed for proximate composition. Every analysis was carried out in duplicate and faeces samples per tank. 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 values: crude protein = 23.9 $kJ \bullet g^{-1}$, crude lipids = 39.8 $kJ \bullet g^{-1}$ and NFE = 17.6 $kJ \bullet g^{-1}$ (Schulz et al. 2005). To estimate the amino acid concentrations of the experimental diets, 5 mg of the freeze-dried samples were hydrolyzed with 6N HCl at 110°C for 24 hours. No protecting reagents were added to avoid destruction of sulphur amino acids. Other analytical procedures for amino acids followed the description of Ogunji and Wirth (2001). Acid Detergent Fibre (ADF) content of magmeal was determined following the method of Van Soest (1963).

Chromic oxide was analysed using the method of Petry and Rapp (1970) with a little correction in preparing the standard solution. Standards used for photometric measurement, and curve determination were prepared with potassium chromate (K_2CrO_4) at concentrations of 10 – 100 $mg \bullet L^{-1}$

Cr^{IV}. Uvikon XL UV/VIS Spectrophotometer (Flowspek Basel CH) was used to measure the extinctions of standard and samples.

The apparent digestibility coefficients (ADCs) of crude protein, crude fat and energy were calculated as follows:

$$ADC = 100 - [1 - (F/D) \times (Di/Fi)]$$ (Cho and Slinger 1979)

$$ADC_{ingr} = [(a + b) \times ADC_{com} - (a) \times ADC_{ref}]$$ (Forster 1999)

where, D = % nutrient or energy of diet; F = % nutrient or energy of faeces; Di = % marker (Cr_2O_3) in diet; Fi =% marker (Cr_2O_3) in faeces; ADC = apparent digestibility coefficient; ingr = ingredient under investigation, ref = reference diet; Com = diet comprised of combination of reference diet and test ingredient; a = nutrient contribution of reference diet to nutrient content of combined diet, = (level of nutrient in reference diet) × (100 – i); b = nutrient contribution of test ingredient to nutrient content of combined diet, = (level of nutrient in reference diet) × i; i = level of test ingredient in combined diet (%); and (a + b) = level of nutrient in combined diet (%)

The apparent digestibility coefficient (ADC) of dry matter was calculated as:

(1 – % Cr_2O_3 in diet/% Cr_2O_3 in faeces) × 100 (Yang et al. 2006).

All data were subjected to one-way analysis of variance (ANOVA) when appropriate. 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

Results of the reference diet, test diet and magmeal analysis are given in table 2, while the analyses of faeces from tilapia and carp respectively receiving experimental diets are shown in table 3. The apparent digestibility coefficients (ADC) for various nutrients of reference and test diets are shown in table 4. The ADC of crude protein for tilapia fed with test diet was lowest (80.11%) and significantly different from carp, however no difference was observed with ADC of crude fat. Table 5 shows that magmeal digestibility of dry matter (47.65%), crude protein (57.7%), crude fat (86.1%) and energy (58.1%) for tilapia are significantly lower than that for carp (dry matter: 63.84%, crude protein: 84.9%, crude fat: 96.8%, energy: 74.9%).

Table 2. Nutrient and amino acid composition of magmeal reference and test diets (%) dry matter

Component	Reference diet	Test diets	Magmeal**
Dry matter	92.86	93.52	92.43
Crude protein	43.17	43.64	46.56
Crude fat	10.98	15.04	25.82
Ash	12.79	12.59	11.10
NFE[1]	33.06	28.73	16.52
Chromium oxide	0.07	0.05	-
Gross energy[2] (kJ•g^{-1})	20.51	21.47	23.36
Amino Acid[3]			
Aspartic acid	6.21	6.76	-
Glutamic acid	10.90	12.48	-
Serine	2.47	2.88	-
Histidine*	2.85	2.78	-
Threonine*	1.57	1.43	-
Arginine*	3.09	3.28	-
Alanine	4.18	3.68	-
Tyrosine	0.51	0.55	-
Tryptophan*	0.72	0.87	-
Valine*	2.78	2.72	-
Phenylalanine*	4.08	4.15	-
Isoleucine*	3.13	3.18	-
Leucine*	1.60	1.61	-
Lysine*	2.51	2.09	-

[1]Nitrogen free extract + fibre, (NFE) = 100 - (% protein + % fat + % ash)
[2]Calculated by: crude protein = 23.9 kJ•g^{-1}, crude lipids = 39.8 kJ•g^{-1}, NFE = 17.6 kJ•g^{-1} (Schulz et al. 2005)
[3]Methionine could not be analysed because of its destruction during acid hydrolysis
*Essential amino acids
** Acid Detergent Fibre (ADF) = 13.78% dry matter

Table 3. Nutrient composition of faeces (%) dry matter*

	Tilapia		Carp	
Component	Reference diet	Test diet	Reference diet	Test diet
Dry matter	31.24±1.6^{a,b}	26.66±1.8^{a}	34.67±2.2^{b}	27.45±1.4^{a}
Crude protein	20.35±0.2^{a}	26.52±2.8^{b}	19.54±0.3^{a}	17.42±1.1^{a}
Crude fat	3.41±1.2^{a}	3.78±1.1^{a}	3.40±0.8^{a}	1.78±0.1^{a}
Ash	41.72±2.3^{c}	26.18±1.0^{b}	42.88±1.0^{c}	31.50±1.7^{a}
NFE	34.51±1.3^{a}	43.52±2.4^{b}	34.17±0.5^{a}	49.30±0.3^{c}
Chromium oxide	0.30±0.0	0.16±0.0	0.23±0.0	0.16±0.0
Gross energy[2] (kJ•g^{-1})	12.30±0.7^{a,b}	15.50±0.5^{c}	12.04±0.3^{a}	13.55±0.1^{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 4. Apparent digestibility coefficients of diets (%)*

	Tilapia		Carp	
Component	Reference diet	Test diet	Reference diet	Test diet
Dry matter	76.71±1.9[b]	67.45±1.7[a]	70.15±1.0[a]	67.68±0.8[a]
Crude protein	89.03±0.8[a]	80.11±2.2[b]	86.50±0.4[a]	87.08±0.8[a]
Crude fat	92.42±3.3[a]	91.56±3.0[a]	90.68±1.6[a]	96.19±0.2[a]
NFE	75.60±2.7[d]	50.90±1.8[b]	69.14±1.1[c]	44.55±1.2[a]
Energy	85.94±1.8[c]	76.42±2.0[a]	82.46±0.8[a,b]	79.60±0.62[b,c]

*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. Digestibility of magmeal in Tilapia and carp diets (%)*

Component	Tilapia	Carp
Dry matter	47.65±1.6[a]	63.84±1.6[b]
Crude protein	57.67±5.1[a]	84.94±1.8[b]
Crude fat	86.08±3.2[a]	96.78±1.7[b]
Energy	58.07±2.5[a]	74.94±1.2[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.

Discussion

In this study, the apparent digestibility coefficient of housefly maggot meal (magmeal) as protein source for Nile tilapia (*Oreochromis niloticus*) and carp (*Cyprinus carpio*) was examined. Due to varying digestive capacities between fish species Degani et al. (1997) suggested the digestibility determination of the nutritional components of fish diets separately for each species. The chromic oxide method of digestibility determination (Austreng 1978) used in this study has been used in several studies of fish feeds. Chromic oxide without any doubt has become the most commonly used external marker in fish as well as in other animals (De Silva and Anderson 1995).

Tilapia and carp fed reference and test diets (CP, 43% DM) in this study recorded protein digestibility ranging from 80% to 89%. These values are similar to those reported by Olvera-Novoa et al. (2002) for tilapia fed diets of anchovy and torula yeast meal (80.5 – 83.20%). Kirchgessner et al. (1986) fed carps with compound feeds of widely varying composition (20 – 60% crude protein and 5 – 20% fat) and obtained a mean value for digestibility of 83% (with a range of 70 – 90%). In the present study, the fat digestibility range of 90.56 – 96.19% for tilapia and carp agree with the

fat digestibility range from 85% to 95% for fish fed with fat sources solely or in a mixed diet (Cho and Slinger 1979; Aksnes and Opstvedt 1998).

This study showed that dry matter, crude protein, crude fat and energy digestibility of test ingredient (magmeal) for tilapia (initial weight; 108.3 g) is significantly lower for carp (initial weight; 110.3 g). This may be attributed to two factors: (1) the effect of reproductive activities of the tilapia used for the experiment and (2) varying faeces consistency in carp and tilapia.

Much sexual movements and spawning by the fish were observed while less food was consumed, resulting in the reduction of feeding level to 2 % for tilapia after 7 days. It has been suggested that digestibility, like any other metabolic process is influenced by both biological and environmental factors, but these factors are still less understood (De Silva and Anderson 1995). The higher nutrient digestibility of carp in contrast to tilapia could also be related to the soft faeces consistency, which promotes nutrient leaching processes. Although faeces collection by siphoning ensured maximum water contact time of 30 minutes, observed soft consistency of carp faeces seemed to support nutrient leaching as described by Brinker et al. (2005). As a result lower protein and fat contents could be observed in faeces of carp (Table 3), which influenced calculated ADCs negatively.

The combined effect of the ADF and ash content of magmeal (13.78 and 11.10% respectively) may have lowered ADCs of dry matter and energy of test ingredient generally. This could have also affected the protein digestibility of magmeal, since dietary ash content has a negative correlation with protein digestibility (Robiana et al. 1997). Köprücü and Özdemir (2005) reported lower ADCs of dry matter, protein, average amino acid, lipid and energy in crayfish exoskeleton meal and gammarid meal than other test ingredients for tilapia due to high content of ash (30.0 and 27.5% respectively) and chitin (10.2 and 6.6% respectively) in the ingredients.

Similarly Degani et al. (1997) reported energy digestibility of carp for fishmeal of 93%, for soybean meal of 75% and for poultry meal of 64%. Low energy digestibility of poultry meal seemed to be caused by high amounts of feathers and keratinized fats in the ingredient. The ADCs of protein in various feed ingredients for Nile tilapia vary from 66% (alfafa) to 94.4% (soybean) (Pompa 1982; Hanley 1987; Fontainhas-Fernandes et al. 1999; Maina et al. 2002). Such variability in ADCs of protein may be explained by differences in chemical composition, origin of

feed ingredients and methods of faeces collection (Köprücü and Özdemir 2005). The high ADCs of fat in magmeal for Nile tilapia (86.08±3.2) and carp (96.78) show that magmeal fat is well digested by the species.

The higher nutrient digestibility of carp observed in this study suggests that carp of about 100g body weight are more able to utilize housefly maggot meal as a protein source than tilapia of similar size. Spawning activities of tilapia and soft faeces consistency of carp may have affected the results. There is a need to repeat this study with carp and tilapia fingerlings.

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