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Mineral status of African catfish (*Clarias gariepinus*) fed diets containing graded levels of soybean or cottonseed meals

Ibrahim Imorou Toko [a,b], Emile D. Fiogbe [b], Patrick Kestemont [a,*]

[a] *Research Unit in Organismic Biology (URBO/FUNDP), 61 rue de Bruxelles, 5000 Namur, Belgium*
[b] *Unité de Recherche sur les Zones Humides (URZH/FAST/UAC), 01BP526 Cotonou, Benin*

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Abstract

In order to assess the effect of increasing levels of dietary soybean meal (SBM) or cottonseed meal (CSM) on growth and body mineral composition of juvenile African catfish, five isonitrogenous (39% crude protein) and isocaloric (13 kJ g^{-1}, digestible energy) diets containing various levels of soybean meal (SBM30 and SBM60) or cottonseed meal (CSM30 and CSM60) as partial replacement of fish meal (Control) were fed to triplicate groups of 50 fish (initial mean weight: 10.3 g) in each tank (0.9 m^3). Over an 8-week feeding period, significant differences ($P<0.05$) were observed on growth, body nutrient and mineral composition between fish fed the experimental diets. Fish fed 600 g kg^{-1} SBM- or CSM-based diets had reduced growth compared to those fed a diet containing 300 g kg^{-1} CSM or the control diet. Survival, feed utilization and hepatosomatic index were not significantly affected by the inclusion level of SBM or CSM in the diets. Fat content was higher in carcass and fillet of fish fed CSM-based diets than those fed SBM- or fish meal-based diets. Body mineral composition in response to dietary treatment revealed a reduction in carcass Ca and P content with the increasing levels of SBM and CSM in the diets while Mg, K, Fe, Zn and Mn content in carcass did not show any marked change ($P>0.05$). However, fish fed SBM- or CSM-based diets have reduced Zn in the fillet than those fed the control diet ($P<0.05$). Moreover, significant correlations were found between body mineral composition and dietary SBM, CSM or phytic acid level, respectively. This study showed that as well as growth is concerned, SBM and CSM can replace fish meal as a source of protein in compound feed for African catfish up to 300 g kg^{-1}. However, in regard to body mineral composition, the inclusion level of these ingredients in the diets should be less than 300 g kg^{-1} and this may be mainly because of the presence of phytic acid in the feed ingredients used.

Keywords: African catfish; Soybean meal; Cottonseed meal; Growth; Mineral composition

1. Introduction

Due to high cost and limited availability of fish meal in many countries, numerous studies on the utilization of soybean meal (SBM) and cottonseed meal (CSM) as partial or complete replacement for fish meal in catfish diets have been conducted during the last decades (Balogun and Ologhobo, 1989; Webster et al., 1995; Phonekhampheng, 1996; Hoffman et al., 1997; Falaye and Ahwieh, 1998; Van Weerd et al., 1999; Fagbenro and Davies, 2001; Imorou Toko et al., 2007a). In general, these studies have shown that replacement of fish meal by inappropriate SBM or CSM levels causes a reduction in growth and reproduction performances and in addition a decrease in feed intake and feed efficiency. Although it is known that these vegetable oil meals contain compounds that can affect the availability of minerals for commonly cultured fish species (Gatlin and Wilson, 1984; Hossain and Jauncey, 1991; Storebakken et al., 1998; Francis et al., 2001; Imorou Toko et al., 2007a), few studies have appraised the mineral composition of African catfish-fed SBM- or CSM-based diets.

Phytic acid is the main antinutrient factor which has a great influence on mineral availability in teleost fish (Hartman, 1979; Papatryphon et al., 1999). Most vegetable feed ingredients used in fish diets contain phytic acid in the range of 5 to 30 g kg^{-1} (Reddy, 2002) and approximately 70% of total phosphorus in SBM and CSM is bound as phytate (Lall, 1991) and therefore not available for fish. Moreover, phytic acid readily chelates di-

* Corresponding author. Tel.: +32 81724363; fax: +32 81724362.
E-mail address: patrick.kestemont@fundp.ac.be (P. Kestemont).

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and trivalent cations such as calcium, magnesium, manganese, iron and zinc at intestinal pH, thus reducing the availability of these minerals (Liener, 1981; Watanabe et al., 1997; Papatryphon et al., 1999). Contrary to trypsin inhibitor and gossypol which are often destroyed by heat treatment during SBM and CSM production process (Herkelman et al., 1991; Bollini et al., 1999; Elmaki et al., 2007), phytic acid is heat-stable (Hardy and Barrows, 2002) and therefore becomes the main antinutrient factor in these plant ingredients, limiting the level of their inclusion in diets for most monogastric animals and fish.

The present study aimed to determine whether the inclusion and levels of dietary SBM and CSM affect the mineral composition of African catfish under rearing conditions.

2. Materials and methods

2.1. Experimental diets

Based on the composition of the main ingredients used (Table 1), five experimental diets were formulated to contain various levels of soybean meal (SBM30 and SBM60) or cottonseed meal (CSM30 and CSM60) as partial replacement of fish meal (Table 2). The control diet was formulated to be similar to a high-quality African catfish diet which usually contains fish meal as the main protein source (about 80% of total protein). Crude protein and energy content were fixed to meet the requirements of African catfish (Degani et al., 1989). All diets were formulated isonitrogenous (about 39% protein) and isocaloric (about 13 kJ g^{-1}, digestible energy). The protein content of the diets was balanced by adjusting maize meal level according to the level of dietary SBM or CSM. Local palm oil (Ovograin Feed Depot, Abomey-Calavi, Benin) and menhaden fish oil (Sigma-Aldrich Chemie, Steinhem, Germany) were used as dietary lipid sources. Blood meal was used as complementary protein source to achieve dietary protein requirements of African catfish. According to El-Saidy and Gaber (2004), iron as ferrous sulfate was used to counteract a possible toxicity of free gossypol in the CSM-based diets.

Diets were prepared by mixing the dry ingredients as described in Imorou Toko et al. (2007a). The diets were stored (4 °C) in airtight plastic sealed bags until used. Ingredients and feed samples were analyzed by standard methods for moisture (oven drying at 105 °C for 24 h), crude protein (N-Kjeldahl × 6.25), fat (extraction with chloroform–methanol, *v/v*, as described by Bligh and Dyer, 1959) and ash (oven incineration at 550 °C), respectively. Digestible energy was estimated from diet ingredients according to New (1987). Diets were also analyzed for mineral composition and phytic acid (Table 3) using the same protocol described in Imorou Toko et al. (2007a).

All of these analyses were conducted at the biochemical laboratory in the Research Unit of Organismic Biology (URBO), University of Namur, Belgium.

Table 1
Proximate composition (dry matter basis), fiber, phytic acid and gossypol of main ingredients used in experimental diets

g kg^{-1}	Fish meal[a]	Soybean meal[b]	Cottonseed meal[b]	Blood meal[c]	Maize meal[b]
Dry matter (fresh matter basis)	920	884	877	846	899
Crude protein	653	414	405	779	105
Crude lipid	96	111	70	6	43
Ash	143	55	80	54	14
Fiber[b]	ns	60	140	ns	22
Lysine[b]	50.3	26.6	16.8	76.2	2.4
Methionine[b]	19.2	6.2	6.0	9.3	1.7
Methionine+Cystine[b]	25.2	12.7	13.3	16.8	3.7
Phytic acid	nd	5.7	3.6	nd	0.4
Gossypol	ns	ns	1.1	ns	ns

ns: not significant; nd: not detectable.
[a] Supplied by Coppens International bv, The Netherlands.
[b] Supplied by 'Ovograin Feed Depot', Benin.
[c] Obtained by heating and sun-drying slaughterhouse blood.

Table 2
Composition (g kg^{-1} dry matter basis) of the five experimental diets

Ingredients	Fish meal	Soybean meal		Cottonseed meal	
	Control	SBM30	SBM60	CSM30	CSM60
Menhaden fish meal	520	330	180	329.2	178.4
Soybean meal	0	300	590	0	0
Cottonseed meal	0	0	0	300	590
Maize meal	290	180	40	180	40
Blood meal	90	90	90	90	90
Menhaden fish oil[a]	30	30	30	30	30
Palm oil[b]	30	30	30	30	30
Vitamin premix[c]	15	15	15	15	15
Mineral premix[d]	15	15	15	15	15
Iron sulfate[b]	0	0	0	0.8	1.6
Carboxymethyl cellulose (binder)[a]	10	10	10	10	10
Proximate composition (g kg^{-1})					
Dry matter (fresh matter basis)	857	871	880	909	884
Crude protein	397	389	388	391	382
Crude lipid	101	115	119	98	86
Ash	99	87	76	96	95
Fiber[e, f]	15	31	45	55	92
Lysine[e, f]	84.9	82.0	81.7	73.9	67.5
Methionine[e, f]	28.5	23.9	20.6	23.8	20.7
Methionine+Cystine[e, f]	39.5	36.8	35.3	37.1	36.6
Digestible energy (kJ g^{-1})[g]	13.7	13.5	13.9	13.6	13.0
Antinutrients (g kg^{-1})					
Phytic acid	0.3	1.5	2.7	1.1	2.2
Phytate[h]	21	138	310	84	165
Gossypol[e]	0	0	0	0.3	0.6

[a] From Sigma-Aldrich Chemie, Steinhem, Germany.
[b] Locally supplied by Ovograin Feed depot, Abomey-Calavi, Benin.
[c] Vit Mix Fish 0.5%, INVE Aquaculture, Belgium (composition per kg: retinol palmitate: 2,500,000 IU; cholecalciferol: 500,000 IU; tocophenol acetate: 30,000 mg ; menadione: 2000 mg ; thiamine: 2000 mg ; riboflavine: 5000 mg ; panthotenic acid: 10,000 mg ; niacin: 5000 mg; pyridoxine: 4000 mg; folic acid: 2000 mg; cyanocobalamin: 4 mg; ascorbic acid: 20,000 mg; biotin: 200 mg and inositol: 80,000 mg).
[d] INRA Belgium, MLNP 763, (composition per kg: dibasic calcium phosphate: 500 g; calcium carbonate: 215 g; sodium chloride: 40 g; potassium chloride: 90 g; magnesium hydroxide: 124 g; iron sulfate: 20 g; zinc sulfate: 4 g; manganese sulfate: 3 g; cobalt sulfate: 0.02 g; potassium iodide: 0.04 g; sodium selenite: 0.03 g and sodium fluoride: 1 g).
[e] By calculation using value in Table 1.
[f] Total protein basis.
[g] Calculated from nutrient content and according to New (1987): 17.8 kJ g animal $protein^{-1}$; 15.9 kJ g plant $protein^{-1}$; 33.5 kJ g $lipid^{-1}$; 12.5 kJ g $carbohydrates^{-1}$.
[h] Total phosphorus basis.

2.2. Fish origin

African catfish, *Clarias gariepinus*, fingerlings were produced by artificial reproduction of captive broodstock at the Research Unit in Wet Land (University of Abomey-Calavi, Benin). Ovaprim® (0.5 ml kg^{-1} of female) was used to induce the females to spawn in an overall procedure similar to that commonly reported for African catfish (Viveen et al., 1985). At hatching (24–29 h after fertilization and incubation at 28 °C), larvae were fed *Artemia* nauplii (EG grade, INVE Aquaculture, Dendermonde, Belgium) for 3 days and then weaned