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SUBSTITUTING FISH MEAL WITH SMOKED FISH WASTE MEAL IN DIETS FOR AFRICAN CATFISH (*CLARIAS GARIEPINUS*)

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Abstract

This study was conducted to evaluate the use of smoked fish waste meal (SFWM) in practical diets for African catfish, *Clarias gariepinus* (8.35 g initial body weight). Six diets were formulated in which SFWM replaced 0.0 (control), 20, 40, 60, 80, or 100% of the protein supplied by herring fish meal (HFM). All diets are isonitrogenous (30.0% crude protein) and isolipidic (9.0% crude lipid). Each diet was used to feed triplicate groups of fish two times a day at a rate of 4 % of fish live body weight at first 8 weeks and 3% for the rest four weeks. Results demonstrated that SFWM had good potential as a complete substitute of the protein supplied by HFM for African catfish. No significant changes were observed in growth performance, feed conversion, and protein utilization compared to fish fed the control diet (100% HFM based diet). Survival rate did not differ significantly among treatments. The partial or complete replacement of SFWM protein for HFM protein in the diets did not affect fish proximate composition (dry mater, crude protein, fat or ash) compared to the control group. Moreover, the economic evaluation showed that a diet containing 100% SFWM reduced the feed cost by 27.39%. In conclusion**,** this study clearly indicates that SFWM can serve as a complete replacement for fish meal in African catfish, *Clarias gariepinus* diets without any adverse effect on growth performance, feed efficiency and survival rate**.**

Keywords: Smoked fish waste meal, African catfish, growth performance, feed efficiency, body composition, economic evaluation.

INTRODUCTION

Aquaculture sector is growing fast worldwide. This rapid development largely depends upon fish meal (FM), which is considered the most desirable animal protein ingredient in aquaculture feeds because of its high protein content, balanced amino acid profile, high digestibility and palatability and as an excellent source of essential n-3 polyenoic fatty acids (Hardy and Tacon, 2002; Li *et al.* 2009; Nguyen *et al.* 2009). Global FM production is approximately 6-7 million tons per year. The continuous increasing demand for fish meal use in animal feed especially in aqua feed has resulted in fish meal becoming difficult to obtain and it is no surprise that FM is the most expensive protein source in animal and aquaculture feeds (Gaber, 2006). Demand for fish meal in feeds for livestock and poultry, is likely to reduce the dependence on fish meal as a single protein source in aqua feeds (El-Sayed, 1999). Therefore, the major challenge facing fish nutritionists is the development of commercial, cost effective fish feeds using locally available, cheap and unconventional resources (El-Sayed, 2004).

The increase cost of FM and concerns regarding its future availability have made it imperative for the aquaculture industry to reduce or eliminate FM from fish diets when possible. So, many studies tried to partially or totally substitute FM with less expensive animal and/or plant protein sources. Despite the fact that large amounts of fishery by–products and by-catch are produced annually in the world, little attention has been paid to the commercial use of these by-products for tilapia (El-Sayed, 2004).

The industry of smocked fish waste meal (SFWM) produced a huge waste rich in protein (% on dry matter basis) and it may be used as a replacer of fish meal in fish diets. That makes SFWM as an acceptable source of animal protein in animals and fish diets. Also, its use could reduce its discharge into the environment.

African catfish, *Clarias gariepinus*, is considered as a candidate of freshwater fish for aquaculture because of its tolerance to a wide range of temperature, low oxygen, high salinity levels, and high fecundity and growth rate (Hecht *et al.*, 1996 and Ote´me´ *et al.* 1996). Moreover, this fish has high nutritive value, good taste, and fewer bones.

Therefore, this study was carried out to evaluate the use of SFWM as a herring fish meal (HFM) substitute in practical diets for African catfish and its relation to fish growth, feed utilization, and whole fish body composition**.**

MATERIALS AND METHODS

Diet preparation and feeding regime:

This study was carried out at the Central Laboratory for Aquaculture Research (CLAR), Abbassa, Abou-Hammad, Sharkia, Egypt. SFWM was a product brought from privet factors (Al-Negma Co.) Giza, Egypt, it consists of some fish not good for smoking and some part of fish such as head, skin, bone and some meat. The chemical analysis of HFM, SFWM and experimental diets are present in Table (1) and Table (2), respectively. Six diets were formulated to be isonitrogenous (30.0 % crude protein) and isolipidic (9.0% crude fat, Table 2). Diet 1 (control) contained herring fish meal (HFM) as a sole source of animal protein, where diet 6 contained SFWM as a sole source of animal protein. Diets from 2 to 5 contained mixtures of HFM and SFWM as sources of animal protein supplements with the proportions of each adjusted so that each of the two ingredients provided similar graded levels of animal protein in the diet. Graded levels of protein replacements were 20, 40, 60, 80 or 100% respectively (Table 3). All diets contained a constant level of plant protein from soybean meal (SBM), corn meal (CM) and wheat bran meal (WBM) to satisfy the protein requirements of African catfish. The ingredients of each diet were thoroughly mixed and blended with additional 100 ml of water per kg diet to make a paste. The pastes were separately passed through a grinder, and palletized (1-mm diameter) in a paste extruder. The diets were oven–dried at 85^{o}C for 24 hours and stored in plastic bags in refrigerator (- 2^{o}C) until use.

Fish culture technique:

African catfish, *C. gariepinus* fingerlings were obtained from Abbassa fish hatchery and acclimated to laboratory condition for two weeks and they were fed a commercial diet containing 30% crude protein. Acclimated fish with an initial body weight of (8.35 ± 0.24 g) were distributed randomly at a rate of 10 fish /120-L glass aquarium. Fish were fed one of the tested diets twice daily at 9.00 and 14.00h at 4 % of body weight for the first eight weeks and 3% for the rest four weeks. Each aquarium was supplied with well–aerated tap water. Each aquarium was also supplied with compressed air produced by a small compressor. The photoperiod was set on a 12 hour light – dark cycle using fluorescent tubes as the light source. Half of aquarium water was siphoned every day for removing the excretory products and refilled with well-aerated tap water. Fish were weighed at the beginning of the experiment and then biweekly for 12 weeks experimental period.

Proximate analysis of diets and fish:

Samples of fish (15 fish) at start of the experiment were taken randomly and were frozen at –20^{o}C for body chemical analysis. At the end, the basal diet and fish samples from each treatment were chemically analyzed according to the standard methods of Association of Official Analytical Chemists AOAC (1990) for determination of moisture, crude protein, total lipids, and ash. Moisture content was estimated by heating samples in an oven at 85^{o}C until constant weight and calculating the weight loss. Nitrogen content was measured using a micro kjeldahl apparatus and crude protein was estimated by multiplying nitrogen content by 6.25. Lipid content was determined by ether extraction for 16 hours and ash was determined by combusting samples in a muffle furnace at 550^{o}C for 6 hours. Crude fiber was estimated according to Goering and Van Soest (1970).

Analysis of water quality parameters:

Water samples were collected biweekly from each aquarium. Water temperature and dissolved oxygen were measured with an oxygen meter (YSI model 58; Yellow Spring Instrument Co., Yellow Spring, Ohio, USA). The pH value was measured using a pH–meter (Digital Mini-pH Meter, model 55, Fisher Scientific, USA**).** Total ammonia was measured using HACH kits (HACH Co., Loveland. Colorado. USA).

Growth Parameters:

Growth performance was determined and feed utilization was calculated as follows:

Weight gain = $W_2 – W_1$;

Specific growth rate (SGR) = 100 ($\ln W_2 – \ln W_1$) / T

Where: W_1 and W_2 are the initial and final weight, respectively, and T is the number of days in the experimental period;

Feed conversion ratio (FCR) = feed intake / weight gain;

Protein efficiency ratio (PER) = weight gain / protein intake;

Protein productive value (PPV %) = 100 × (protein gain/ protein intake),

Energy utilization (EU, %) = 100 (energy gain in fish / energy intake in feed).

Economical evaluation:

The cost of feed required to produce a unit of fish biomass was estimated using a simple economic analysis based on the local market price of all ingredients at the time of the study. These prices (in LE/kg) were as follows: herring fish meal, 12; soybean meal,3.5; corn meal, 2.25; wheat brain 2.0; starch 3.0; fish oil, 9.0; corn oil, 6.0; vitamin premix, 9.0; mineral mixture 3.0 and SFWM, 2.5 LE/kg.

Statistical analysis:

The obtained data of fish growth, feed utilization, survival rate, and proximate chemical composition were subjected to one-way ANOVA. Differences between means were tested at the 5% probability level using Duncan test. All the statistical analyses were done using SPSS program version 10 (SPSS, Richmond, USA) as described by Dytham (1999).

RESULTS AND DISCUSSION

The values of water quality parameters in all treatments showed that, dissolved oxygen concentrations ranged from 5.9 to 6.5 mg L^{-1}. The ambient water temperature range was 26–27 °C. The pH range was 7.9–8.2, and unionized ammonia concentration ranged from 0.1 to 0.15 mg L^{-1}. Total alkalinity and total hardness ranges were 130–175 mg L^{-1} as CaCO3, and 125–180 mg L^{-1} as CaCO3, respectively. All the previous water parameters are within the acceptable ranges for fish growth (Boyd, 1984).

The chemical analysis of the ingredients (Herring fish meal HFM, smoked fish waste meal SFWM, soybean meal SBM, corn meal CNM and wheat bran meal WBM) and diets are presents in Table 1 and 2, respectively. Based on the results SFWM analysis is a good alternative protein source and may replace HFM protein in African catfish diets. All African catfish fingerlings became accustomed to the experimental diets and were observed to feed actively throughout the duration of this study. Initial body weigh at all experimental treatments did not differ significantly (Table 3). The present study showed that growth performance (final body weight, weight gain, growth rat and specific growth rate) was not significantly ($P > 0.05$) differed. All diets were well accepted by African catfish. These observations suggested that the SFWM diets contained all the necessary growth factors required by African catfish. The isoniterogenous, isolipidic, and isocaloric nature of the experimental diets explained why there was no disparity in growth response of fish and efficiency of feed utilization. The 100% replacement of HFM by SFWM in the present study coincide with the results obtained by Ahmad and Diab (2008),who reported that Nile tilapia fed diets, in which SFWM replaced up to 100% of the protein supplied by HFM, had similar growth performance. Li *et al* (2009) found that there were no significant differences in weight gain (WG), final body weight (FBW), nitrogen retention efficiency (NRE), energy retention efficiency (ERE) and total nitrogen waste output (TNW) between fish fed the control diet (herring meal) and the diet containing 75% substitution of herring meal by poultry by-product meal (PBM) for malabar grouper *Epinephelus malabaricus*. Also, Seden and Ahmad (2011) found that poultry by product meal (PBM) had good potential as a complete substitute of the protein supplied by HFM for African catfish. On the other hand, El-Marakby *et al*. (2010) found that African catfish growth was not affected by replacement of fish meal by poultry hatchery waste meal up to 80%, after which fish growth was reduced. Hussein *et al*, (2012) reported that growth performance of African catfish fed diet containing 100% substitution had significantly ($P > 0.05$) lower final body weight and weight gain than those fed diet containing 25, 50 and 75% substitution of fish meal with PBM. Also, results of the present study did not coincide with the results obtained in previous studies for red tilapia, *Oreochromis niloticus x O. mossambicus* by Abdelghany, 2003, and for gibel carp, *Carassius auratus gibelio* by Yang *et al*. 2006). Survival rate content of African catfish fed all the treatments did not differ significantly. It was high 100 % of the fish (Table 3), these results agreed with that found by Seden and Ahmad (2011). Also, Li *et al* (2009) found that there was no significant difference in survival rate among fish fed on poultry by product meal and fish fed on fish meal.

In the present study, fish diets in which SFWM substitute up to 100% of the protein supplied by HFM had similar feed utilization efficiency (feed intake FI, feed conversion ratio FCR, protein efficiency ratio PER, protein productive value PPV and energy utilization EU) compared to the fish fed the HFM-based diet (Table 4). These results similar with the results of Ahmad and Diab (2008) who found that SFWM can substitute HFM in Nile tilapia diets at 100% level without significant retardation in feed efficiency. Also, these results agreed with the results of Diab and Ahmad (2008) who reported that Nile tilapia fed diets in which PBM replaced up to 100% of the protein supplied by HFM had similar FI, FCR, PER and EU% to that fed the HFM–based diet. Similarly, Seden and Ahmad (2011) showed that, African catfish fed diets in which PBM subsidize up to 100% of the protein supplied by HFM had similar FI, FCR, PER and PPV% to that fed the HFM–based diet. On the other hand, Ahmad (2008) found that highest growth and protein utilization for Nile tilapia was obtained at the rate of 75% gambosia fish meal to replace HFM**.** El-Marakby *et al.* (2010) found that feed utilization estimated for African catfish diet containing different poultry hatchery waste meal levels were higher than those in fish fed the control diet. In general, partial or complete replacement of SFWM for HFM protein in the experimental diets for African catfish may have amino acid profiles that meet the requirements of this species. These results demonstrated African catfish herein that amino acid profile of SFWM is as good as HFM and the quality of protein in terms of the quantitative essential amino acids of both ingredients are similar.

In the present study, the proximate chemical analysis (dry matter, crude protein, total lipid and ash) of whole African catfish body were not significantly affected by SFWM inclusion in the fish diets (Table 5).

These results indicated that the partial or complete replacement of HFM by SFWM protein did not alter the nutritional value of the fish produced. These results also suggested that African catfish efficiently ingested, digested, assimilated and utilized protein from SFWM similar to HFM. Similar results were obtained by Abdelghany *et al* (2005), Diab and Ahmad (2008) and Li *et al* (2009), they found no significant changes in whole–body moisture and fat content resulted from the different replacement levels of fish meal with poultry by product meal PBM. On the other hand, El-Marakby *et al.* (2010) who observed no significant difference in whole body composition (dry matter, protein, fat and ash) of African catfish fingerlings fed on diets in which up to 60% of herring fish meal had be replaced with poultry hatchery waste meal. Moreover, Hussein *et al*, (2012) reported that the partial or complete replacement of HFM by PBM did not affect body composition (dry matter, protein, fat and ash) of African catfish.

The economical evaluation of the experimental diets contained different SFWM levels to replace 20%, 40%, 60%, 80% and 100% of HFM are shown in Table (6). The cost of diet to produce one kg fish gain was gradually reduced, by increasing the profitability of producers. The cost to produce one kg of the experimental diet compared with the cost of control diet showed that the lowest cost was obtained when the diet contained 100% SFWM. The reduction in feed cost to produce one kg fish gain using the diet containing 100% SFWM compared with the control diet was 27.39%. The high improvement of the production cost by replacing the HFM by SFWM products in the present study were coincide with the results obtained by Ahmad and Diab (2008) for Nile tilapia *Oreochromis niloticus*. Similarly, this results agrees with that found in previous studies by Diab and Ahmad (2008), El-Marakby *et al.* (2010), Seden and Ahmad (2011) and Hussein *et al*, (2012), they found that the highest reduction in feed cost was obtained by diet containing

100 % Poultry by product meal or poultry hatchery waste for Nile tilapia and African catfish, respectively.

Table 1. The proximate chemical compositions of the main ingredients (% DM-basis) used in the experimental diets.

Ingredients	Dry matter	Crude Protein	Crude Lipid	Fiber	Ash
HFM[1]	91.80	72.02	14.80	2.17	10.70
SFWM[2]	86.22	40.03	25.40	1.20	23.6
SBM[3]	93.81	44.02	1.27	7.5	6.87
CNM[4]	90.17	9.30	3.77	4.14	1.20
WBM[5]	89.80	15.30	4.20	9.80	5.80

[1]- Herring fish meal, [2]- Smoked fish waste meal, [3]- Soybean meal, [4]- Corn meal, [5]- Wheat bran meal.

Table 2. The compositions and proximate chemical analysis of formulated diets used in this experiment.

Ingredients	**SFWM levels (%)**					
	0.0	20	40	60	80	100
HFM	9.1	7.3	5.5	4.5	1.8	0.0
SFWM	0.0	3.3	6.5	8.2	13.0	16.3
Soybean meal	46.5	46.5	46.5	46.5	46.5	46.5
Corn meal	19.2	19.2	19.2	19.2	19.2	19.2
Wheat bran	10.9	10.9	10.9	10.9	10.9	10.9
Starch	6.6	5.6	4.7	4.4	3.0	2.0
Cod liver oil	3.1	2.6	2.1	1.7	1.0	0.5
Corn oil	2.6	2.6	2.6	2.6	2.6	2.6
Vitamin premix[1]	1.0	1.0	1.0	1.0	1.0	1.0
Mineral premix[2]	1.0	1.0	1.0	1.0	1.0	1.0
Total	100	100	100	100	100	100
Chemical analyses:						
Dry matter	92.1	91.7	91.8	92.0	91.6	91.9
Crude protein	30.3	29.9	30.0	30.5	29.8	30.1
Total lipids	9.1	9.0	8.9	9.0	8.9	9.2
Ash	7.5	7.7	7.8	7.9	8.0	8.1
Crude fiber	5.6	5.3	5.7	5.9	5.6	5.8
NFE[3]	47.5	48.1	47.6	46.7	47.7	46.8
GE (kcal/100g) [4]	453.5	451.7	449.2	449.3	448.5	449.3

[1] Vitamin premix (per kg of premix): thiamine, 2.5 g; riboflavin, 2.5 g; pyridoxine, 2.0 g; inositol, 100.0 g; biotin, 0.3 g; pantothenic acid, 100.0 g; folic acid, 0.75 g; para-aminobenzoic acid, 2.5 g; choline, 200.0 g; nicotinic acid, 10.0 g; cyanocobalamine, 0.005 g; α-tocopherol acetate, 20.1 g; menadione, 2.0 g; retinol palmitate, 100,000 IU; cholecalciferol, 500,000 IU.

[2] Mineral premix (g/kg of premix): $CaHPO_4.2H_2O$, 727.2; $MgCO_4.7H_2O$, 127.5; KCl 50.0; NaCl, 60.0; $FeC_6H_5O_7.3H_2O$, 25.0; $ZnCO_3$, 5.5; $MnCl_2.4H_2O$, 2.5; $Cu(OAc)_2.H_2O$, 0.785; $CoCl_3.6H_2O$, 0.477; $CaIO_3.6H_2O$, 0.295; $CrCl_3.6H_2O$, 0.128; $AlCl_3.6H_2O$, 0.54; Na_2SeO_3, 0.03.

[3] Nitrogen-Free Extract (calculated by difference) = 100 – (protein + lipid + ash + fiber).

[4] Gross energy (GE) was calculated according to NRC (1993) as 5.65, 9.45, and 4.11 kcal/g of protein, lipid, and carbohydrates, respectively.

Table 3. Growth performance (means ± SE) of African catfish fed six diets containing SFWM at graded replacement levels for HFM on protein unit basis.

Items	SFWM levels (%)					
	0.0	**20**	**40**	**60**	**80**	**100**
Initial weight (g)	8.50± 0.23	8.40± 0.22	8.30± 0.20	8.20± 0.30	8.40± 0.30	8.30± 0.10
Final weight (g)	48.53± 0.40	48.81± 0.58	47.57± 0.33	48.47± 0.38	47.70± 0.58	48.10± 0.52
Weight gain (g)	40.03± 0.63	40.41± 0.34	39.27± 0.35	40.27± 0.22	39.30± 0.40	39.80± 0.88
Growth rate (g/day)	0.48± 0.03	0.48± 0.2	0.47± 0.03	0.48± 0.03	0.47± 0.02	0.47± 0.02
SGR (% g/day)	2.07± 0.02	2.09± 0.02	2.08± 0.02	2.12± 0.03	2.07± 0.02	2.09± 0.02
Survival rate (%)	100	100	100	100	100	100

Table 4. Feed intake FI, Feed conversion ratio FCR, Protein efficiency ratio PER, Protein productive value PPV% and Energy utilization EU (means ± SE) of African catfish fed six diets containing (SFWM) at graded replacement levels for (HFM) on protein unit basis.

Items	SFWM levels (%)					
	0.0	**20**	**40**	**60**	**80**	**100**
FI (g feed/fish)	58.60± 0.35	59.20± 0.24	58.10± 0.49	59.30± 0.46	58.50± 0.81	58.00± 0.92
FCR	1.46± 0.03	1.46± 0.02	1.48± 0.02	1.47± 0.02	1.49± 0.03	1.46± 0.05
PER	2.45± 0.03	2.49± 0.02	2.45± 0.02	2.41± 0.01	2.45± 0.02	2.46± 0.05
PPV%	57.19± 0.81	58.96± 0.31	57.0± 0.58	56.91± 0.10	57.82± 0.11	56.67± 0.22
EU	31.20± 0.46	32.15± 0.49	29.87± 0.61	29.93± 0.58	31.31± 0.57	29.40± 0.60

Table 5. Proximate composition (% on dry weight basis) of whole body of African catfish fed six diets containing SFWM at graded replacement levels for HFM on protein unit basis.

Items	SFWM levels (%)					
	0.0	20	40	60	80	100
Dry matter	27.1±0.9	27.5±1.1	26.9±0.7	27.1±0.8	27.3±1.3	26.8±0.7
Crude protein	67.1±0.8	66.8±1.1	66.7±0.9	67.1±1.0	67.5±0.7	66.9±0.9
Ether extract	17.7±0.5	18.2±0.8	17.9±1.0	18.0±0.4	17.8±0.3	17.9±0.9
Ash	14.0±0.3	13.9±0.6	14.5±0.9	14.2±0.7	14.4±0.8	14.8±0.7

Table 6. Economic efficiency for production of one (Kg) gain of African cat fish fed six diets containing SFWM at graded replacement levels for HFM on protein unit basis.

Items	SFWM levels (%)					
	Control 0.0	20 %	40 %	60 %	80 %	100 %
Price/ kg feed, L.E	4.27	4.04	3.80	3.68	3.43	3.10
Reduction in feed cost,%	0.0	5.39	11.01	13.82	19.67	27.4
Feed cost / kg gain L.E	6.28	5.98	5.59	5.45	5.11	4.56
Reduction in feed cost / kg gain,%	0.0	4.78	10.99	13.22	18.63	27.39

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استبدال مسحوق السمك بمخلفات الرنجة المدخنة فى علائق أسماك القرموط الإفريقى

أمل سيد حسن ، مدحت السعيد سيدين ،
طلعت ناجى عامر ، نادر عزت الطويل

المعمل المركزى لبحوث الثروة السمكية – مركز البحوث الزراعية.

الملخـــص العربـــى

أجريت هذه الدراسة لتقييم مدى إمكانية استبدال مسحوق السمك بمسحوق مخلفات الرنجة المدخنة فى علائق أسماك القرموط الإفريقى. تم تكوين ستة علائق تجريبية استبدل فيها مسحوق السمك بمسحوق مخلفات الرنجة بنسب مختلفة كما يلى: صفر(كنترول)، ٢٠، ٤٠، ٦٠، ٨٠، ١٠٠ % على أساس نسبة البروتين حيث كانت جميع العلائق تحتوى على (نسبة بروتين٣٠% ودهن بنسبة ٩%) وتمثل كل معاملة بثلاث مكررات بكل منها ١٠ سمكات (بمتوسط وزن ٨.٣٥ جم/سمكة). غذيت الأسماك على العلائق التجريبية بمعدل ٤% من الوزن الحى للأسماك لمدة ثمانية أسابيع ثم ٣% لمدة الأربع أسابيع الباقية للتجربة التى استمرت ١٢أسبوع . وفى نهاية التجربة أشارت النتائج إلى أن أفضل مستوى استبدال لمسحوق السمك كان مستوى ١٠٠% من مسحوق مخلفات الرنجة ولم تلاحظ أى تغيرات معنوية مقارنة بالعليقة الكنترول، كذلك لم تكن هناك أى فروق معنوية فى معدلات النمو ومعدلات الاستفادة من البروتين مقارنة بالعليقة الكنترول، كما أوضحت النتائج أن الإحلال الكلى لمسحوق السمك بمسحوق مخلفات الرنجة لم يؤثر على تركيب الجسم (المادة الجافة – البروتين الخام – الدهن الخام– الرماد) مقارنة بالعليقة الكنترول.علاوةً على ذلك أوضح التقييم الاقتصادى أن العليقة المحتوية على ١٠٠% من مسحوق مخلفات الرنجة خفض التكاليف الكلية للغذاء بنسبة ٢٧.٤%. مما سبق وتحت ظروف التجربة فيمكن التوصية باستخدام مسحوق مخلفات الرنجة بدلاً من مسحوق السمك بنسبة ١٠٠% من العليقة دون أن يؤثر ذلك على أداء النمو أو كفاءة الاستفادة من الغذاء لأسماك القرموط الإفريقى بالإضافة إلى تحسين الكفاءة الإقتصادية وانخفاض التكلفة مقارنة بالعلائق التى تحتوى على مسحوق السمك.