



**International Journal of Biology, Pharmacy
and Allied Sciences (IJBPAS)**

'A Bridge Between Laboratory and Reader'

www.ijbpas.com

**GROWTH PERFORMANCE OF *Channa striata* (Bloch 1793) FED WITH DIETS
ENRICHED WITH PLANT AND ANIMAL PROTEINS AND SYNTHETIC AMINO
ACIDS WITH IMPROVED NUTRITIONAL PROFILE**

VIJAYARANI. Y* AND P. PADMAVATHI

Department of Zoology and Aquaculture, Acharya Nagarjuna University, Nagarjuna Nagar – 522 510,
Guntur, Andhra Pradesh, India

*Corresponding Author: Vijayarani. Y: E Mail: vincyeruva@gmail.com

Received 22nd March 2020; Revised 23rd April 2020; Accepted 20th May 2020; Available online 1st Nov. 2020

<https://doi.org/10.31032/IJBPAS/2020/9.11.5496>

ABSTRACT

The nutrition and feeding of freshwater fishes have achieved significant advances in the world today regarding the zootechnical performance of aquatic organisms as a whole. To sustain aquaculture, research has been focused on the nutrition and aquafeed production in recent years using alternative protein sources. As a primary protein source in aquafeeds especially for carnivorous fishes like murels, fish meal (FM) has been used as an excellent source of proteins, lipids, essential amino acids, vitamins, etc. There is a need to develop balanced feeds with a lower monetary cost for the food of striped snakehead murrel, *Channa striata* (Bloch 1793) [4] which do not cause zootechnical and environmental damage and still maintain animal health. This will help the technical and economic viability of the commercial culture of this species. This work aimed to seek feed formulations capable of providing a reduction in the monetary cost of balanced diets for the culture of *Channa striata*, by decreasing the level of inclusion of salmon flour in food mixtures with an improved nutritional profile. Results indicated that in basal diets with 51.4% salmon flour and 16.1% soybean meal, the maximum substitutions beyond this level, without compromising the performance of the feeds, were achieved by supplementing synthetic amino acids in food mixtures with improved nutritional profile. This nutritional approach showed that diets with soybean meal inclusion reduce 17.9% of the cost of formulating the feed which could be feasible for adoption by local feed industries.

Keywords: *Channa striata*, synthetic amino acids, salmon flour, soybean meal, food mixtures

1.0. INTRODUCTION

Channa striata (striped snakehead murrel) is a freshwater fish commonly found in waters, including rivers, lakes, swamps, and can even live in waters with low oxygen content [19]. Murrels have high economic value, both fresh and preserved, or in dry conditions [10]. Srivastava [20] states that snakehead fish can live in fresh and brackish waters even in dry water conditions; these fish can survive by burying themselves in the mud. According to Hamid *et al.* [7] the growth of snakehead fish is better in artificial feed containing 40% protein, but in general, the growth is still low, presumably because the protein digestibility is not optimal. Protein digestibility is largely determined by the type of raw food material, water temperature, enzyme activity, and bacteria in the digestive tract of fish [12]. The quality of feed is very much determined by the nutritional content of the raw material. Therefore the provision of high-quality feed needs to be done by considering digestibility so that these nutrients can be utilized properly. Fish needs nutrients in the form of protein, fat, carbohydrates, vitamins and minerals whose needs are different according to the age and type of fish [25].

The addition of the vegetable protein, animal protein in feed has been shown to increase protein digestibility in several fish

species, including snakehead fish [5]. Yu *et al.* [24] also stated that giving various proteins at a dose of 2.25% had a better effect on the survival and growth of *Channa striata*. Furthermore, according to Tran Thi Thanh Hien *et al.* [22] the addition of soyaprotein in artificial feed was able to increase the growth rate, survival and protein retention in the meat (muscle) of *Channa striata*. Therefore it can be said that the protein and amino acid requirements for snakehead fish has occurred from vegetable and animal proteins. So far, research on the effect of vegetable and animal proteins on the level of protein utilization in artificial feed and growth rate of snakehead fish has not been carried out. Therefore it is important to determine the optimal dose of protein for the growth of snakehead fish. This study aims to determine the optimal dose of artificial feed with enhanced nutritional profile and the growth rate of snakehead fish (*Channa striata*).

2.0. MATERIALS AND METHODS

2.1. Culture System

This study was carried out in polyethylene cylindrical tanks of 0.5 and 1 m³ each of 25 units kept in a covered area (indoor), operating on a recirculation regime with continuous water filtration. To reduce the incidence of light on the tanks, a shading structure was built.

2.2. Experimental Design

The present study was designed and carried out in two consecutive experimental stages. In the 1st stage, the zootechnical performance of *C. striata* was evaluated against reductions in the dietary profile of essential amino acids. In this experimental stage, five diets were formulated, one basal diet containing 51.4% of salmon flour and 16.1% of soybean meal. Four other diets were formulated from the basal diet by substituting salmon flour with soybean meal in 12, 25, 37 and 50% (Table 2). A commercial extruded diet for freshwater fish with a slow sinking was used as control. The first experimental stage was carried out in three levels, each varying in the capacity of culture system, water recirculation regime, fish stocking density, initial body weight and duration of culture (Table 1). In the second stage, *C. striata*

juveniles fed with diets in which salmon flour was gradually replaced with vegetable or animal protein concentrates as two food mixtures (Table 3) with an improved nutritional profile. These mixtures or concentrates were formulated and prepared in the laboratory using plant and animal proteins (Table 2) and synthetic amino acids (Table 2) these are not given in Table 2. Initially, a diet from the 1st experimental stage was chosen to serve as a control. From this diet, reductions were made in the inclusion of salmon flour of the order of 25, 50 and 75%, to allow the inclusion of protein concentrates based on plants and animal proteins. In this stage of the study, juveniles of murrel weighing 15 ± 3 g (n = 75) were stocked at a density of 6-7 fish/m³ in 25 polyethylene tanks of 1 m³. The fishes were cultured for 70 days.

Table 1: Operational characteristics of each experimental level of culture in the evaluation of the zootechnical performance of juveniles of *C. striata*

1 st Experimental Stage			
	Level 1	Level 2	Level 3
Volume of tanks	One Cubic meter	Half Cubic meter	Half Cubic meter
Number of tanks	25	25	25
Water exchange regime	Periodic weekly changes	Continuous recirculation and filtering	Continuous recirculation and filtering
Initial body weight	12.6 ± 2.36 g (n =100, CV = 12.67 %)	14.69 ± 09.24 g (n =75, CV = 19.24%)	15.62 ± 02.35 g (n =75, CV = 6.95%)
Stock density	6 fish / m ³	7 fish / m ³	7 fish / m ³
Initial weight of Juveniles	8.2g to 376.3± 3.70 g	8.2g to 376.3± 3.70 g	8.2g to 376.3± 3.70 g
Number of diets	6 diets, one commercial	6 diets, one commercial	5 experimental diets
Duration of culture	41 days	56 days	70 days

2.3. Formulation of the diets

Experimental diets and protein mixes or concentrates with improved nutritional profiles were formulated using Feedsoft Professional 10.0 linear formulation software.

2.3.1. Ingredients used in the formulation of diets:

A. Plant proteins: Soybean meal (*VijayaSaradhi Feeds, Andhra Pradesh* - 47.65% CP; 3.21% EE; 6.07% ash; 4.18% CF; 10.33% humidity); Soy protein concentrate (*Process Agrochem Ltd.* - 61.20% crude protein (CP); 1.60% ether extract (EE); 5.77% ash; 3.55% crude fiber (CF); 7.40% humidity); Corn gluten (*Corn Products Brasil Ingredients purchased from Yeastin Aqua, Vijayawada, India* - 65.79% CP; 2.67% EE; 1.37% ash; 1.74% CF; 7.56% humidity); Wheat Flour (*White Rose Wheat Flour* [13.41% CP; 2.17% EE; 1.24% ash; 0.74% CF; 11.04% humidity).

B. Animal proteins: Meat and bone meal (53.32% CP; 18.43% EE; 21.00% ash; 1.15% CF; 7.00% humidity); Feather meal (*Arsh Kamal Co.Ltd .India* [74.79% CP; 10.73% EE; 4.65% ash; 0.80% CF; 9.00% humidity); Salmon flour (*Meat flour from farmed salmon processing purchased from Pacific Star S.A., Maharashtra, India* - 62.82% crude protein (CP); 10.73% of ether extract (EE); 15.56% ash; 0.06% crude fibre (CF); 9.87% humidity); Chicken offal meal (60.53% CP; 17.34% EE; 0.76% ash; 0.76% CF; 7.20%

humidity); Salmon oil (*Amway Nutrilite Salmon Omega -3*); Squid flour (*Kingmei Feeds, Naga Hanuman Feeds, Bhimavaram* -73.00% CP; 7.30% EE; 8.00% ash; 2.70% CF; 9.00% humidity); Sardine hydrolyzate (71.80% CP; 9.60% EE; 13.70% ash; 6.05% humidity).

C. Synthetic amino acids: Arginine; Cystine; Histidine; Isoleucine; Leucine; Lysine; Methionine; Phenylalanine; Threonine; Tryptophan; Tyrosine and Valine.

L-Lysine HCl (*U. K. Vet Chem, Maharashtra, India* - 78% lysine (minimum); 93.4% CP; 1.5% humidity); DL-Methionine (*DL-methionine 99%, animal feed grade. 99% methionine* - 58.1% CP; 0.5% ash; 1.5% humidity).

D. Vitamins and Minerals: Premix vitamin-mineral (*DSM Shrimp Nutritional Products* -(Ingredients per one Kilogram): vitamin A, (1,000,000 IU); vitamin D3 (300,000 IU) vitamin E (15,000 IU) vitamin K3, (300.0 mg); vitamin B1, (3,000.0 mg); vitamin B2, (2,500.0 mg); vitamin B6, (3,500.0 mg); vitamin B12, (6.0 mg); nicotinic acid, (10,000.0 mg); pantothenic acid, (5,000.0 mg); biotin, (100.0 mg); Folic acid, (800.0 mg); vitamin C, (25,000.0 mg); choline, (40,000.0 mg); inositol, (20,000.0 mg); iron (2,000.0 mg); copper, (3,500.0 mg); chelated copper, (1,500.0 mg); zinc, (10,500.0 mg); chelated zinc, (4,500.0, mg); manganese, (4,000.0

mg); selenium, (15.0 mg); chelated selenium, (15.0 mg); iodine, (150.0 mg); cobalt, (30.0 mg); chromium, (80.0 mg); vehicle, (1,000.0 g); Vitamin C (Sera SERA-KOI-MINI-900 -L-ascorbic acid-2-monophosphate, $Na_2CaO,5C_6H_6O_9P$); Monocalcium phosphate (CAPHOS Feed Supplement, BIOMAACX Nutri science, Ravulapalem); Magnesium sulphate; Potassium chloride.

Food Mixtures/ Protein concentrates:

Soy protein concentrate; Corn gluten; Salmon oil; L-Lysine HCl₄; Monocalcium phosphate ; Sardine hydrolyzate DL-Methionine; Magnesium sulphate; Offal flour; Meat and bone meal; Wheat Flour; Feather meal; Potassium chloride.

Synthetic binder (Synthetic binder based on urea-formaldehyde - Krill Pellet Fix Binder); Ethoxiquin (Crystal Pharma, India - 66.6% in powder form).

Commercial extruded diet: Proveg Engineering & Food Processing Private Limited, Dist. West Godavari, AP., India - Crude protein (51.76 %), ethereal extract (6.59%), crude fiber (1.5%), ash (11.02%), moisture (11.47%), non-nitrogen extract (29.13 %) and gross energy (18.5 MJ/kg).

2.3.2. Diets of the 1st Experimental Stage

For this experimental step, the nutritional approach adopted in the formulations was based on the work of Munir *et al.* [14]. In

the present study, the basal diet contained 51.40% salmon flour and 16.10% soybean meal. From this diet, 12, 25, 37 and 50% salmon flour were substituted by soybean flour (Table 2). Soybean meal was incorporated at the expense of reductions in salmon and Rice bran, the latter used as a vehicle in the feed. The fat content of the diets accompanied with the reduction in the salmon flour. To balance the fat content of the diets, the supply of salmon oil was increased. Whole squid flour was used as an attractant and flavouring agent in all diets at 2.0%. A synthetic binder based on urea-formaldehyde was incorporated in the inclusion of 0.7% to promote greater physical integrity. In this experimental stage, the experimental diets reached a level of crude protein (CP), ether extract (EE) and gross energy (GE) of \cong 54 (coefficient of variation (CV) = 1.39%), 13.5 ± 0.50 % (CV = 3.7%) and 20.1MJ / kg (CV=4.7%), respectively. Comparatively, the commercial diet evaluated contained 51.76% CP, 6.60% EE and 18.49 MJ / kg of GE. In experimental diets, the percentage of ash was directly proportional to the reduction of salmon flour. The non-nitrogen extract and the gross energy increased proportionally with greater inclusions of soybean meal. The diets were formulated to contain 601.5 mg/kg of polyphosphate ascorbic acid (PAA).

2.3.3. Protein Concentrates with improved nutritional profile

Food mixtures/protein concentrates with an improved nutritional profile were prepared in the laboratory from vegetable ingredients and proteins from the slaughter of terrestrial fishes (**Table 3**). The raw materials were selected to act as the most significant proteins in protein concentrates. The soy protein concentrate (62.44%) and poultry slaughtering meal (61.92%) were used in the inclusions, respectively, in vegetable (VPC) and animal (APC) concentrates.

Salmon oil (HK Basics Co. Ltd. India) was added to both concentrates to compensate for deficiencies in the polyunsaturated fatty acid profile (PUFAs), while sardine hydrolyzate was used to promote greater palatability. The concentrates were also supplemented with synthetic amino acids, L-LysineHCl and DL-Methionine. All inputs of raw materials and additives in protein concentrates had the objective of approaching the nutritional profile of

salmon flour while seeking a reduction in the monetary cost. The costs of formulating vegetable and animal protein concentrate relative to salmon flour's value were reduced by 47.5 and 43.8%, respectively.

2.3.4. Diets of the 2nd Experimental Stage

These diets replaced salmon flour in 25, 50 and 75% with food mixtures or vegetable (VPC) and animal (APC) protein concentrates, with an improved nutritional profile (**Table 4**). The diets were formulated isoproteins (55%, CV = 1.1%), isolipids (12%, CV = 4%) and isoenergetic (19.9 MJ/kg, CV = 1.49%). All experimental diets followed the same composition of ingredients as the control diet, with the exception of wheat flour and salmon oil, which suffered reductions as the substitution of soybean meal increased. In this experimental stage, the substitutions of salmon flour for protein concentrates achieved a reduction in the monetary cost in the formulation, from 17.2 to 78.8% through the use of VPC, and from 17.9 to 83.7% with APC.

Table 2: Ingredients and Proximate composition of five diets used in the 1st experimental stage

Diet/(% of diet, natural basis) ¹	1	2	3	4	5	Commercial
Ingredients	Basal	12%	25%	37%	50%	
Salmon Flour ²	51.4	45	38.5	32.1	25.7	---
Soybean meal ³	16.1	24.6	33	41.5	50	---
Rice bran	10	7.53	5.05	2.58	0.11	---
Corn gluten ⁴	10	10	10	10	10	---
Salmon oil	5.67	6.1	6.52	6.95	7.37	---
Squid flour ⁵	2	2	2	2	2	---
Premix vitamin-mineral ⁶	2	2	2	2	2	---
Magnesium sulphate	1.1	1.1	1.1	1.1	1.1	---
Synthetic binder ⁷	0.7	0.7	0.7	0.7	0.7	---
Monocalcium phosphate ⁸	0.7	0.7	0.7	0.7	0.7	---
Potassium chloride	0.3	0.3	0.3	0.3	0.3	---
Vitamin C ⁹	0.03	0.03	0.03	0.03	0.03	---
Ethoxyquin 66% ¹⁰	0.01	0.01	0.01	0.01	0.01	---
Proximate composition (% of diet, dry basis)¹¹						
Crude protein	52.65	53.52	54.27	54.38	54.48	51.76
Ethereal extract	12.75	13.5	13.53	13.99	13.98	6.59
Crude fiber	1.17	1.68	2.12	2.29	2.82	1.5
Ash	23.5	19.94	14.91	13.79	10.7	11.02
Moisture	10.56	10.91	11.01	10.66	10.86	11.47
Non-nitrogen extract ¹²	9.93	11.36	15.17	15.55	18.02	29.13
Gross energy (MJ / kg) ¹³	17.8	18.5	19.4	19.6	20.1	18.5

¹Percentage of substitution of salmon flour with soy meal.

²Meat flour from farmed salmon processing purchased from Pacific Star S.A., Maharashtra, India. [62.82% crude protein (CP); 10.73% of ether extract (EE); 15.56% ash; 0.06% crude fibre (CF); 9.87% humidity].

³VijayaSaradhi Feeds, Andhra Pradesh[47.65% CP; 3.21% EE; 6.07% ash; 4.18% CF; 10.33% humidity]

⁴Corn ProductsBrasil Ingredients purchased from Yeastin Aqua, Vijayawada, India [65.79% CP; 2.67% EE; 1.37% ash; 1.74% CF; 7.56% humidity].

⁵KingmeiFeeds,Naga Hanuman Feeds, Bhimavaram[73.00% CP; 7.30% EE; 8.00% ash; 2.70% CF; 9.00% humidity].

⁶DSM Shrimp Nutritional Products

⁷ Synthetic binder based on urea-formaldehyde (Krill Pellet Fix Binder).

⁸CAPHOS Feed Supplement, BIOMAX Nutri science, Ravulapalem.

⁹ [Sera SERA-KOI-MINI-900].L-ascorbic acid-2-monophosphate, Na₂CaO₅C₆H₆O₉P

¹⁰Etoxiquin, 66.6% in powder form, Crystal Pharma, India

¹¹Results analyzed in triplicate and duplicate by the respective laboratories.

¹² Calculated by difference (100 - CP - EE - CF - ashes).

¹³Calculated from "Energy protein, fat and carbohydrate value of 5.64 kcal/g, 9.44 kcal/g and 4.11 kcal/g, respectively".

Table 3: Ingredients and proximate composition of vegetable and animal protein concentrates, with amino acid profile.

Ingredients	Market value per Kg/Litre (Rs) ¹	Salmon Flour	Protein Concentrate (%)	
			Animal	Vegetable
Soy protein concentrate ²	80-00	---	62.44	---
Corn gluten ³	49-00	---	20	---
Salmon oil ³	879-00	---	8.7	3.2
L-Lysine HCl ⁴	830-100	---	3.14	3.17
Monobicalcium phosphate ³	37-00	---	2.08	---
Sardine hydrolyzate ⁵	70-00	---	2	2
DL-Methionine ⁶	6.44	---	1.57	1.51
Magnesium sulphate	299	---	0.08	---
Offal flour ⁷ (Poultry meal)	140-00	---	---	61.92
Meat and bone meal ⁸	110-00	---	---	19.89
Wheat Flour ⁹	27-00	---	---	6.81
Feather meal ¹⁰	7.50	---	---	0.83
Potassium chloride	34-00	---	---	0.67
Formulation cost (Rs)	---	3750.00	2250-00	2360-00
Proximate composition (%. Dry basis) ¹¹				
Crude protein		64.3	55	55
Digestible protein		54.05	45.58	36.28
Ethereal extract		10.01	12	17.97
Crude fibre		0.09	2.74	0.76
Ash		14.85	4.62	12.81
Moisture		10.10	6.34	6.87
Total energy (MJ / kg)		17.6	18.4	18.9
Digestible energy (MJ / kg)		15.1	12.3	12.8
Amino acid profile (%. Dry basis) ¹¹				
Arginine		6.26	3.22	3.4
Cystine		0.76	0.77	0.73
Histidine		2.25	1.23	0.95
Isoleucine		3.75	2.3	1.86
Leucine		6.59	4.97	3.42
Lysine		6.75	5.77	5.77
Methionine		2.78	2.38	2.38
Phenylalanine		3.95	2.77	1.8
Threonine		3.83	1.93	1.04
Tryptophan		0.61	0.6	0.38
Tyrosine		3.38	2.04	1.48
Valine		4.64	2.49	2.46

¹ Prices collected in the market on 16/09/2018

² Process Agrochem Ltd [61.20% crude protein (CP); 1.60% ether extract (EE); 5.77% ash; 3.55% crude fiber (CF); 7.40% humidity].

³ For composition, see Table.1

⁴ U. K. Vet Chem, Maharashtra, India [78% lysine (minimum); 93.4% CP; 1.5% humidity].

⁵ 71.80% CP; 9.60% EE; 13.70% ash; 6.05% humidity.

⁶ DL-methionine 99%, animal feed grade. 99% methionine; [58.1% CP; 0.5% ash; 1.5% humidity. ⁷ 60.53% CP; 17.34% EE; 0.76% ash; 0.76% CF; 7.20% humidity]

⁸ 53.32% CP; 18.43% EE; 21.00% ash; 1.15% CF; 7.00% humidity

⁹ White Rose Wheat Flour [13.41% CP; 2.17% EE; 1.24% ash; 0.74% CF; 11.04% humidity].

¹⁰ Arsh Kamal Co.Ltd .India [74.79% CP; 10.73% EE; 4.65% ash; 0.80% CF; 9.00% humidity.

¹¹ Values were estimated based on the results obtained from the formulations

Table 4: Ingredients and proximate composition of diets used in the 2nd Experimental stage

Diet / Composition (% of the diet. Natural basis) ^{1,2}	
Vegetable Protein Concentrate	Animal Protein Concentrate

Ingredients	Control	25%	50%	75%	25%	50%	75%
Salmon Flour ³	44.63	33.47	22.32	11.16	33.47	22.32	11.16
Soybean meal ³	22.17	22.12	22.12	22.12	22.12	22.12	22.12
Vegetable protein concentrate ⁴	0	13.56	27.06	40.57	0	0	0
Animal protein concentrate ⁴	0	0	0	0	13.3	26.55	39.8
Corn gluten ³	10	10	10	10	10	10	10
Wheat Flour ⁴	11	9.13	7.25	5.37	10.19	9.37	8.55
Salmon oil ³	5.36	4.88	4.41	3.93	4.08	2.81	1.53
Premix vitamin-mineral ³	2	2	2	2	2	2	2
Sardine hydrolyzate ⁴	2	2	2	2	2	2	2
Magnesium sulfate	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Synthetic binder ³	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Monobicalcium phosphate ³	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Potassium chloride	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Vitamin C ³	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Etoxiquin 66% ³	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Formulation cost (Rs./100kg) ²	2702.00	2654.00	1924.00	2084.95	2644.91	2350.55	2055.84
Formulation cost reduction (%) ⁵	---	17.2	41.6	78.8	17.9	43.6	83.7
Proximate composition (% of the diet. Dry basis) ⁶							
Crude protein	54.67	54.4	54.29	54.28	55.3	55.86	54.18
Ethereal extract	12	12.08	12.21	12.25	11.83	11.93	10.83
Crude fiber	1.47	1.77	2.5	2.67	1.61	1.67	1.95
Ash	12.63	11.68	10.57	8.96	12.91	13.49	13.14
Moisture	10.63	10.62	10.48	9.11	8.43	7.11	10.34
Non-nitrogen extract ⁷	19.23	20.06	20.43	21.83	18.35	17.05	19.91
Gross energy (MJ / kg) ⁸	19.5	19.7	19.7	20	19.4	19.4	19.1

¹ Percentage of substitution of salmon flour for protein concentrate.

² Prices collected in the market details given in Table3

³For composition, see Table1.

⁴For composition, see Table2.

⁵Reduction in the monetary value of the formula relative to the control diet.

⁶Centesimal composition analyzed (Results analyzed in triplicate).

⁷Calculated by difference (100 - CP - EE - CF - ashes).

⁸Calculated using a protein, fat and carbohydrate energy value of 5.64 kcal/g, 9.44 kcal/g and 4.11 kcal/g, respectively

2.4. Preparation of experimental diets

The preparation of the experimental diets started with the grinding of dry raw materials in a simple centrifugal mill in 600 µm mesh [13]. The micro-ingredients (minerals, vitamins, etc.) and the wheat flour were not subjected to grinding or sifting, as they had a fine particle size. Subsequently, all ingredients (solids and liquids) were weighed on an electronic balance and mixed in an industrial planetary mixer for pasta for 10 min

(Miranda Limited Company, Mumbai, India). The micro-ingredients and the crushed soybean meal were mixed in a Y homogenizer (Noble Homogenizer for Food Processing, India). They added to the other ingredients preceding the mixture in a planetary mixer. After this process, it was boiled. Freshwater was added to the mixture of ingredients until it reached more than 30% moisture, being mixed for an additional time of 10 min. This mixture was subjected to extrusion in a laboratory dry

expansion extruder (Azeus Fish Feed Machinery, India). The diets were produced with a matrix of 2.0 and (or) 3.5 mm.

During the extrusion, food filaments were formed, which were distributed in steel trays for drying at 60°C in an oven with air circulation and renewal for about 2 h. The dough was turned over every 10 min. drying time, when aliquots were removed to determine the moisture content in an analyser (MoistTech IR-3000) to achieve homogeneous every diet. At the end of the drying process, the diets were cooled to room temperature and the pellets were broken in a domestic food processor, sieved to remove the fines, packed in plastic bags, identified and stored at -22°C. The commercial feed was milled and repelled in the laboratory, adopting the same procedures as before.

2.5. Feed management

The fish were fed daily between 08:00 and 14:00 hours, exclusively in feeding trays measuring 300 mm in diameter (706.8 cm²). The food was offered by keeping the trays suspended in half water. The fish were initially fed at a rate of 10% of the biomass. Subsequently, meals were calculated based on leftover rations, when observed in feeding trays, 3h after the food was offered. When leftovers from the previous meal were observed equal to or greater than 10% of the original meal, the next meal was reduced by 10%. When

leftovers were less than 10%, the next meal was kept constant. Meals were increased only when there was no leftover food (**Figure 1**).

In the 2nd experimental stage, the feeding trays were replaced by trays with higher edges (from 3 to 5 cm) to reduce the ejection of feed pellets to the bottom of the tanks at the time of feeding. In both levels, daily siphoning was performed to remove waste and uneaten feed from the bottom of the tanks. Due to this management combined with the action of decanters and shading, the water in the cultivation tanks remained in full visibility throughout the experiment.

2.6.1. Proximate composition of diets:

Proximate Analysis is a partitioning of compounds in a feed into six categories based on the chemical properties of the compounds [2]. The six categories are:

- moisture
- ash
- crude protein (or Kjeldahl protein)
- crude lipid
- crude fibre
- nitrogen-free extracts (digestible carbohydrates)

This analysis (**Figure 2**) was an attempt to duplicate animal digestion. After extracting the fat, the sample is subjected to an acid digestion, simulating the acid present in the stomach, followed by an alkaline digestion, simulating the alkaline environment in the

small intestine. The crude fiber remaining after digestion is the portion of the sample assumed not digestible by monogastric animals. In the proximate analysis of feedstuffs, Kjeldahl nitrogen, ether extract,

crude fiber and ash are determined chemically. The determination of nitrogen allows the calculation of the protein content of the sample.

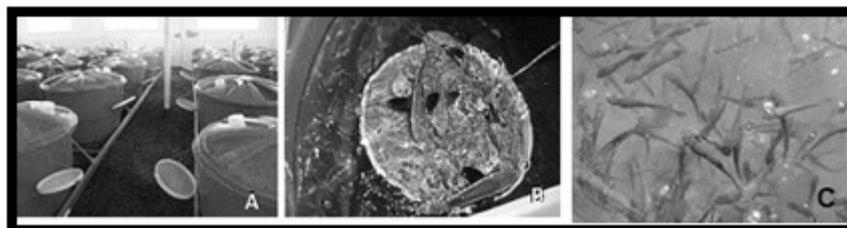


Figure 1: (A) Feeding trays used during the experimental stage in indoor tanks. (B) & (C) Tray immersed in water offering food to juveniles of *Channa striata*

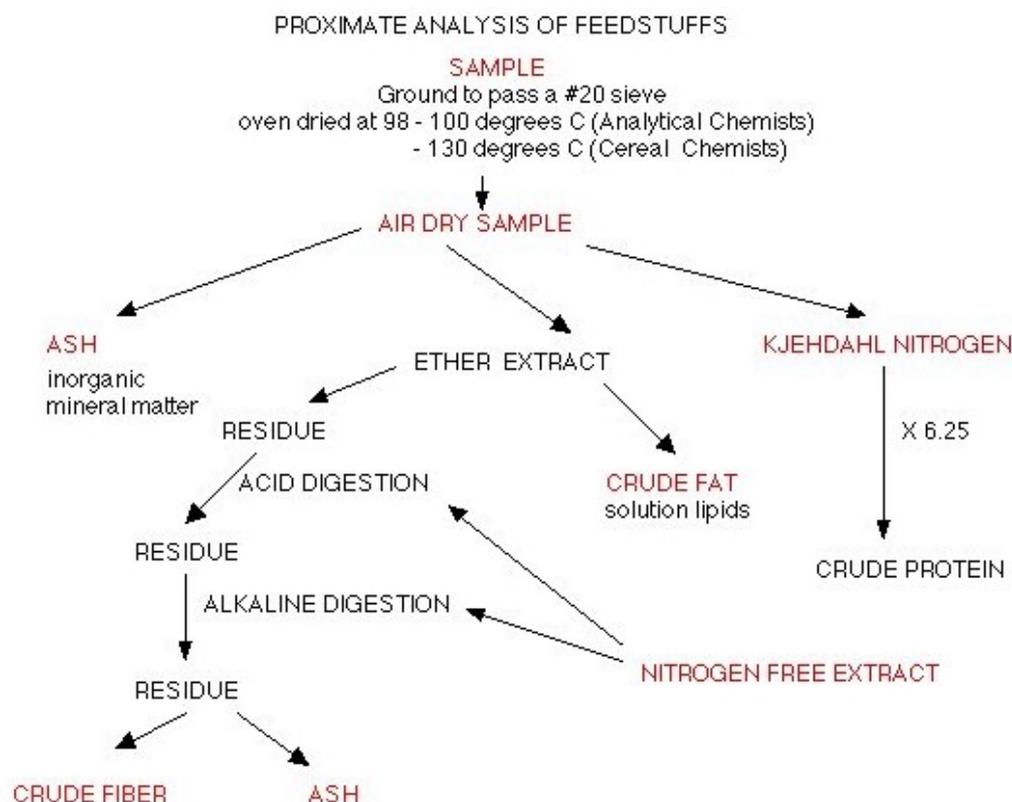


Figure 2: Schematic representation of proximate composition of diets

2.6.2. Estimation of Amino acids: The amino acid profile of fish meal was carried out by following the HPLC method described by White *et al* [23] Quantification was performed in HPLC [Shimadzu HPLC model SPD-10AT VP]

with fluorescence detectors. The samples were hydrolysed with 6N HCl at 110 ° C for 24 hours. A set of amino acid patterns was analyzed for each sample. The identification of the amino acids in the

samples was performed by comparing the retention times of the standards.

2.7. Water quality: The physico-chemical parameters of water in each cultivation tank were monitored daily. A portable pH meter was used to determine the pH (Water Quality Analyzer PE 138 – Elico). A digital oxymeter was used to determine the dissolved oxygen and temperature (Aquaculture oxygen sensor OXY 1002). Alkalinity, nitrite, nitrate and total ammonia levels were estimated following the standard methods (APHA, 1985).

2.8. Zootechnical Performance Index

The zootechnical performance indexes were determined by following the methods of El-Haroun *et al.*, [6].

- Specific growth rate of the fish (% SGR),
- Average Daily weight gain (ADG in g/day),
- Survival rate of fish (% SR),
- Percentage Weight Gain (%) and
- Feed conversion factor (FCR)

The feed conversion factor of the diets was determined at the end of the culture using apparent food consumption (FCa, in g / tank / cycle). The apparent consumption of diet was calculated by the difference between the amount of ration offered and the leftovers redeemed in the food trays. Both the feed offered and the collected leftovers were subtracted from moisture.

2.9. Statistical Analysis

Statistical analyses were performed using the Statistical Package for Social Sciences program, Windows 10. The ANOVA was applied to determine the statistical differences between treatments. The Tukey's HSD (Honestly Significant Difference) test was used to examine the individual statistical differences between treatments at the significance level of 0.05.

3.0. RESULTS

3.1. Water quality of culture tanks: The water quality parameters remain unchanged relatively throughout the experimental period and the values are given in **Table 5**.

3.2. Zootechnical performance: 1st Experimental stage

Zootechnical performance of *C. striata* juveniles fed with experimental diets in three levels of 1st Experimental stage are given in **Table 6**. Survival, ADG, WG, SGR and FCR showed statistical difference between diets in at least one of the evaluated culture levels.

Final survival, daily and percentage weight gains, specific growth rate and FCR of *C. striata* juveniles, grown for 41, 56 and 70 days (levels 1, 2 and 3 of the 1st experimental stage) with diets with the progressive replacement of salmon flour by soybean meal. Values are presented as mean \pm standard deviation (SD). Similar letters in each column indicate a non-significant statistical difference according

to the Tukey's HSD a posteriori test at the significance level of $\alpha = 0.05$ (Table 6).

The survival of the fish was negatively affected when fed with the commercial diet, and to a lesser extent, with the diet with 50% replacement of salmon flour (level 1 & level 2, Table 6). Except for level 1, there was no effect of the diet on the survival of juveniles. In terms of ADG, WG and SGR, there was a reduction in these values as we sought to reduce salmon flour inclusions. However, this reduction was significant when using the commercial diet (levels 1 and 2, $P < 0.05$, Tukey's HSD).

In case of level 3, these parameters also reduced proportionally to an increase in the replacement of salmon flour, with a significant drop after 25% of substitution. The diet with 50% substitution of salmon flour led the juveniles to a much lower zootechnical performance compared to other experimental diets. At this stage, the FCR also deteriorated due to the level of substitution for salmon flour, although only in diets with 37 and 50% substitution, a statistical difference ($P < 0.05$, Tukey HSD) was observed.

At harvest, the final body weight of fish varied according to the dietary treatment (Figure 3). In the level 1 of 1st experimental stage, juveniles fed diets with a replacement of salmon flour greater than 12% underwent a significant reduction in

body weight ($P < 0.05$, ANOVA). Both in levels 1 and 2, fish fed the commercial diet had the lowest body weight among all treatments evaluated. In level 3, juveniles did not present a detriment in the final body weight until 25% of substitution of salmon flour. In this case, the weight of the juvenile fish showed no difference in the levels of substitution of salmon flour 25 and 37% and between the diets with 50% substitution and the commercial one ($P > 0.05$, ANOVA). In general, data on the final body weight of fish pointed to the viability of substituting salmon flour with soybean meal between 12 and 25%. Quadratic regression analysis ($y = 993 + 73.93x + 0.78x^2$ where $x =$ percentage weight gain, $R^2 = 0.83$) indicated that the optimal level of inclusion of soybean meal, without loss in the gain of weight of, *C. striata* was 47.9%. The results also indicated an equivalence of the commercial diet with the diet with the highest substitution level for salmon flour.

3.3. Zootechnical performance: 2nd Experimental stage

In the 2nd experimental stage, the survival of *C. striata* after 84 days of culture was more than 92% for most dietary treatments. The fish survival was only negatively affected when replacing salmon flour with vegetable protein concentrate (VPC) at 75% level (Table 7). The zootechnical

performance parameters related to the growth of *C. striata* (ADG, WG and SGR) were affected in lower levels of salmon flour substitution. For example, levels of substitution of fish meal for both vegetable and animal protein concentrates above 25% have already shown a reduction in the *C. striata* growth rates in relation to the control diet ($P < 0.05$, Tukey's HSD). However, it was found that the species was less tolerant to substitutions of salmon flour for vegetable protein concentrate, compared to the animal. The FCR, for example, deteriorated significantly at substitution levels of 75% with the use of vegetable protein concentrate ($P < 0.05$, Tukey's HSD). The specific growth rate (SGR) was reduced by using vegetable protein concentrate in 50% and 75% substitutions. In contrast, this parameter remain unchanged for the animal protein concentrate in relation to the control diet ($P > 0.05$, Tukey's HSD). When analysing the final body weight of the fish, the same

tendency to reduce performance was observed (**Figure 4**). When seeking substitutions for salmon flour greater than 25%, a reduction in the fish body weight occurred. However, at 50% substitution level, APC provided a higher body weight compared to VPC for *C. striata*.

The results of zootechnical performance of *C. striata* in this experimental stage were consistent with those obtained in the 1st experimental stage. Both the growth rate and the body weight were affected by the levels of salmon flour substitutions. However, in the 2nd experimental stage, it was verified that both the survival and FCR can also be compromised when looking for very high substitutions of salmon flour. The reduction in the monetary cost in the formulations, without compromising juveniles' zootechnical performance of *C. striata*, reached a maximum of 17.9% on the control diet containing 44.63% of salmon flour.

Table 5: Water Quality Parameters during the two experimental stages

Water Quality parameter	1 st Experimental Stage			2 nd Experimental Stage
	level -1	Level -2	Level -3	
pH	7.30 - 8.12	7.30 - 8.12	7.1 - 8.89	7.02 - 8.80
alkalinity (mg/L as CaCO ₃)	139-173	139-173	153	148.2
Ammonia (mg/L)	0.97-2.24	0.97-2.24	0.97-2.24	0.41

nitrite (mg / L)	0.016-0.029	0.016-0.029	0.016-0.029	0.35
nitrate (mg / L)	0.52-0.35	0.52-0.35	0.52-0.35	1.58
Dissolved oxygen (DO)	3.30 - 5.60	2.8 to 7.8	3.8 – 6.9	4.10 - 7.46
Salinity (g/L)	35-41	36 - 41	35.9 - 40.9	35 - 40
Temperature (°C)	29.1	29.3	29.2	26.6 – 29.9

Table 6: Zootechnical Performance Parameters

Experimental Diet	Zootechnical Performance Parameters				
	Survival (%)	ADG (g / day)	WG (%)	SGR (% / day)	FCR
Level 1					
Basal diet	79.00 ± 28.0	2.32 ± 0.4 ^a	522 ± 23 ^a	5.20 ± 0.1 ^a	1.19 ± 0.23
12 %	86.00 ± 13.0	2.19 ± 0.3 ^a	548 ± 18 ^a	4.80 ± 0.2 ^a	2.11 ± 1.47
25%	99.00 ± 0.9	2.37 ± 0.2 ^a	604 ± 26 ^a	5.30 ± 0.4 ^a	1.23 ± 0.18
37%	99.20 ± 0.02	2.77 ± 0.4 ^a	564 ± 24 ^a	5.20 ± 0.3 ^a	1.39 ± 0.27
50%	76.00 ± 39.3	1.19 ± 0.3 ^a	485 ± 33 ^a	4.80 ± 0.2 ^a	1.72 ± 0.23
Commercial	49.00 ± 45.6	1.31 ± 0.4 ^b	260 ± 27 ^b	3.60 ± 0.9 ^b	2.98 ± 1.13
Mean ± SD	81.00 ± 29.34	---	---	---	1.84 ± 0.91
ANOVA P	0.527	< 0.001	< 0.002	< 0.0001	0.114
Level 2					
0 %	99.00 ± 0.02 ^a	2.61 ± 0.4 ^a	369 ± 22 ^a	2.70 ± 0.1 ^a	1.61 ± 0.10 ^a
12 %	99.00 ± 0.02 ^a	2.22 ± 0.3 ^a	330 ± 28 ^a	2.60 ± 0.3 ^a	1.59 ± 0.17 ^a
25%	99.10 ± 0.02 ^a	2.77 ± 0.4 ^a	375 ± 22 ^a	2.90 ± 0.5 ^a	1.49 ± 0.15 ^a
37%	96.00 ± 09.3 ^a	2.26 ± 0.8 ^a	322 ± 30 ^a	2.40 ± 0.5 ^a	1.64 ± 0.54 ^a
50 %	88.00 ± 10.3 ^{ab}	2.92 ± 0.6 ^a	261 ± 29 ^a	2.90 ± 0.4 ^a	1.50 ± 0.23 ^a
Commercial	66.00 ± 0.24 ^b	1.83 ± 0.1 ^b	140 ± 20 ^b	1.70 ± 0.3 ^b	5.64 ± 0.22 ^b
Mean ± SD	---	---	---	---	---
ANOVA P	0.0069	< 0.0001	0.003	< 0.0001	< 0.0001
Level 3					
0 %	100.00 ± 0.0	2.11 ± 0.1 ^a	781 ± 60 ^a	3.20 ± 0.2 ^a	1.47 ± 0.50 ^a
12%	100.00 ± 0.0	2.34 ± 0.4 ^a	759 ± 80 ^a	3.20 ± 0.2 ^{ab}	1.72 ± 0.56 ^a
25%	97.00 ± 8.2	2.00 ± 0.2 ^{ab}	703 ± 20 ^{ab}	3.20 ± 0.1 ^{ab}	2.08 ± 0.21 ^a
37%	100.00 ± 0.0	2.10 ± 0.2 ^b	614 ± 40 ^b	2.30 ± 0.3 ^b	2.72 ± 0.44 ^{ab}
50%	100.00 ± 0.0	1.30 ± 0.4 ^c	316 ± 37 ^c	2.70 ± 0.4 ^c	4.53 ± 2.66 ^b
Mean ± SD	99.00 ± 3.7	---	---	---	---
ANOVA P	0.426	< 0.0001	< 0.0001	< 0.0001	< 0.0001

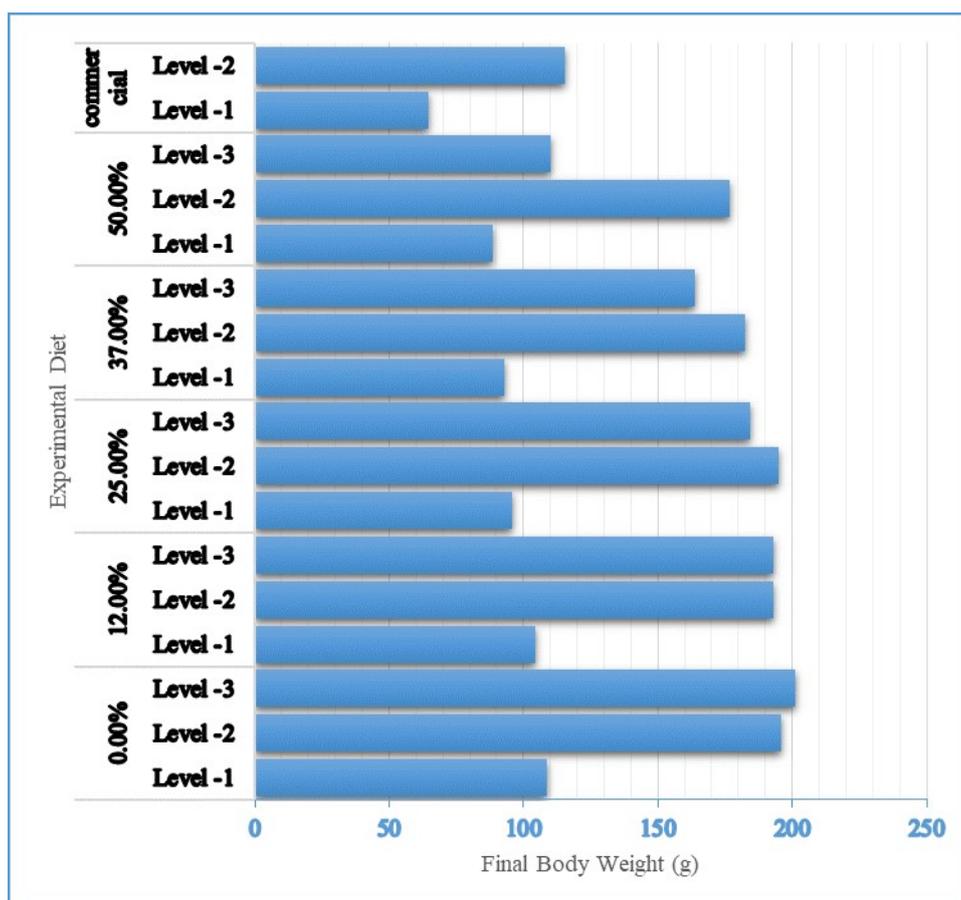


Figure 3: Final body weight (mean ± standard error) of the *C. striata* in the 1st experimental stage, against the substitution of 12, 25, 37 and 50% of salmon flour with soybean meal

Table 7: Final survival, daily and percentage weight gains, specific growth rate and FCR (feed conversion ratio) of *C. striata* juveniles, cultivated for 84 days on diets with progressive replacement of salmon flour with a vegetable (VPC) and animal protein concentrate (APC) with improved nutritional profile.

Experimental Diet	Zootechnical Performance Parameters				
	Survival (%)	ADG (g/day)	WG (%)	SGR (%/Day)	FCR
Control	100.00 ± 0.0 ^a	2.42 ± 0.12 ^a	1412 ± 142 ^a	3.12 ± 0.2 ^a	1.29 ± 0.14 ^a
25 % VPC	100.00 ± 0.0 ^a	2.14 ± 0.20 ^{ab}	1319 ± 131 ^{ad}	3.32 ± 0.4 ^a	1.69 ± 0.13 ^a
50 % VPC	93.40 ± 6.0 ^a	1.61 ± 0.42 ^c	918 ± 101 ^b	2.08 ± 0.5 ^{bd}	1.77 ± 0.21 ^a
75 % VPC	81.34 ± 12.04 ^b	0.27 ± 0.10 ^d	436 ± 72 ^c	2.04 ± 0.4 ^c	4.19 ± 2.74 ^b
25 % APC	99.97 ± 0.01 ^a	2.53 ± 0.11 ^a	1262 ± 34 ^a	3.11 ± 0.11 ^a	1.62 ± 0.18 ^a
50 % APC	96.32 ± 2.37 ^a	2.08 ± 0.22 ^b	1091 ± 100 ^d	3.06 ± 0.1 ^{ab}	1.74 ± 0.03 ^a
75% APC	99.70 ± 2.01 ^a	1.45 ± 0.21 ^c	916 ± 19 ^b	2.71 ± 0.10 ^d	1.91 ± 0.58 ^a
ANOVA P	< 0.002	< 0.001	< 0.004	< 0.005	< 0.020

* Values are presented as mean ± standard deviation (SD). Values indicating different letters in each column are significant at P<0.05.

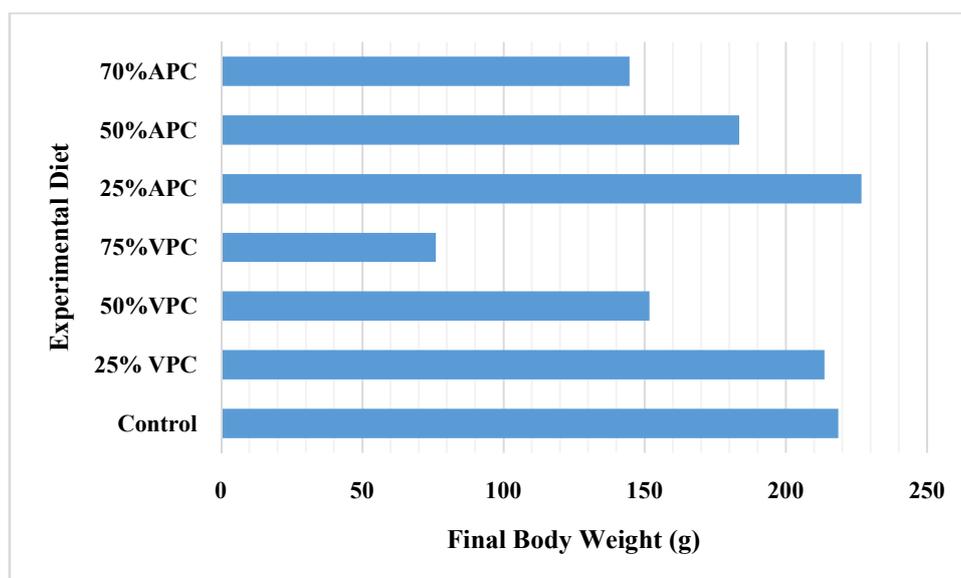


Figure 4: Final body weight (mean \pm standard error) of *C. striata* in the 2nd experimental stage, compared to substitutions of 25, 50 and 75% in a control diet containing 44.63% of salmon flour by a vegetable protein concentration (VPC) and animal (APC) with improved nutritional profile

4.0. DISCUSSION

In the present work, when using protein concentrates, using soy protein concentrate and poultry flours as basic proteins, the maximum levels of substitution in a diet containing 44.63% wheat flour salmon was 25.0%. Comparatively, while Yu *et al.* [24] managed to use a diet with only 24.7% fishmeal, 15.0% corn gluten, 13.6% soy protein concentrate, 8.0% soy protein isolate, in the present study, these values were 33.47% fishmeal, 22.12% soybean meal and 10.0% corn gluten, in addition to the concentrates used. Although it is not possible to compare diets based solely on the inclusion of ingredients, but rather, using levels of essential nutrients, the differences show that *C. striata* is capable of efficiently using a variety of alternative ingredients.

In recent years, numerous studies have been carried out seeking to replace fish meal with alternative proteins [21, 24]. Hien *et al.* [10] concluded that, in a diet for striped snake head murrel juveniles containing 50.0% fish meal and 11.5% soybean meal, it was possible to replace up to 60% with a poultry meal, without commitment to species performance. Hien *et al.* [9-10] concluded that in diets containing 50.0% fishmeal and 11.3% soybean meal, the maximum substitution level for poultry meal was 30.75%. On the other hand, Abdul Hamid *et al.* (2018) [1] worked with 49.90% fish meal diets and 15.0% corn gluten. The authors were able to replace up to 50% of the fish meal with a combination of 13.6% soy protein concentrate, 8.0% soy protein isolate, and

supplementation with methionine and betaine.

The present study showed that the commercial feed used did not provide satisfactory zootechnical performance for juveniles of *C. striata*, although it had a crude protein content and ether extract (dry basis) of 51.2% and 6.6%, respectively. In terms of zootechnical performance, the commercial feed was equivalent to the experimental diet that continues to have the largest inclusions of soybean meal, in the order of 50.0%. Although it is not possible to speculate on the composition of commercial feed ingredients, it is possible that the results below the desired level were due to a very low level of ether extract and a content of non-nitrogen extract (NNE), of 29.13 %, very high in the ration. The experimental diets reached an EE content of $13.55 \pm 0.51\%$ and an NNE between 9.93 and 18.02%. The commercial feed's gross energy content was 18.02 MJ / kg, not unlike the experimental diets. However, it is estimated that a significant share of this commercial feed energy was derived from carbohydrates, a poorly digestible component for freshwater carnivorous species. Therefore, it can be speculated that the low zootechnical performance of commercial feed was the result, among other factors, of a little digestible energy in the feed. Unlike commercial feed, a significant portion of experimental diets'

gross energy was derived from lipids, a highly digestible component for freshwater fish [15].

There are contradictions in relation to the lipid requirements of *C. striata* reported in the literature [8]. The works carried out on this theme, by Sagada *et al.* [17], point out that the species has a requirement of 5.76% of lipids. The authors reported that diets containing 31.0% of fish meal with 11.5% of soybean meal, and with up to 18.9% of lipids (dry basis), did not result in better growth for juveniles of *C. striata*, Samanta Ray *et al.* [19] worked with striped snake head murrel juveniles with a body weight of 7.4 g and 185.9 g. The authors fed the animal's diets with two levels of crude protein (CP), 40 and 50%, and three levels of lipids, 6, 12 and 18%, resulting in crude energy levels of 14.4 to 15, 1 KJ / g of diet. According to the authors, when grouped by lipid content, the best results in weight gain and food efficiency of striped snake head murrel was achieved with diets containing 12.0% of total lipids. Diets containing 6% of lipids returned intermediate values. The results of diets containing 18% were significantly lower than those of the others. These results contradict what is observed at the commercial level in Asia. Freshwater fish fattening diets can contain a lipid content of up to 18% [2]. According to Paul *et al.*, [16], in India and other Asian countries, striped snake head murrel is

grown with diets containing 48% crude protein (PB) and 18% lipids (dry basis), while in the United States, they are manufactured commercial operations with excessive levels of CP, around 58% and 15% of lipids (dry basis). The high lipid content of Asian diets, according to the authors [19], is attributed to the fact that striped snake head murrel, in these countries, is destined for the sashimi market, which requires a greater deposition of fat in the meat. Despite these results, other studies with striped snake head murrel nutrition, point out that the commercial rations that result in a better zootechnical performance of the species are those that contain higher levels of fat. In a recirculation system, Sagada *et al.* [18] stocked striped snake head murrel Juveniles with a body weight of 26.7 ± 0.9 g under an initial density of $1.2 \text{ kg} / \text{m}^3$. The fish were fed three commercial diets manufactured in the USA for carnivorous fish, containing 50% crude protein (CP), 22% ether extract and 0.94% methionine (diet A); 49% CP, 17% EE and 0.91% methionine (diet B), and; 48% CP, 17% EE and 0.61% methionine. After 57 days of cultivation, the fish fed with diet (A) achieved significantly higher zootechnical performance (203.3 g of body weight, 3.6% / day of specific growth rate and $7.3 \text{ kg} / \text{m}^3$ biomass) compared to fish fed with other diets. According to the authors, it was

found that diets with a high lipid content have a protein-sparing effect and promote greater growth in Juveniles of Striped snake head murrel.

The only way to seek a reduction in the cost associated with the use of balanced feeds for species is to better understand their nutritional requirements, in addition to identifying ingredients and additives capable of minimizing the economic impact of the formulation, without compromising zootechnical performance. However, it was observed that Juveniles of striped snake head murrel present a high nutritional requirement, digestible amino acids and highly unsaturated fatty acids of long chain (PUFAs). In the present study, the species' nutritional requirements were only fully met when using salmon flour in high inclusions above 30%. When seeking to replace this ingredient with soybean meal, the species' optimum growth was achieved with minimum inclusion of 45.0% of salmon flour. With food mixes with an improved nutritional profile, the species' optimum growth can be achieved with 33.5% salmon flour. Other studies have shown that it is possible to use diets for striped snakehead murrel Juveniles with even lower inclusions of fish meal. Tran *et al.* (2017), working with 32 g striped snakehead murrel Juveniles for eight weeks achieved optimum growth of the species with 26.9% fishmeal and 28.6% soybean

meal. The authors reported that the level of methionine in diets with the highest substitution of fish meal was the likely restrictive factor for the growth of the species [3]. In this study, the diet with the maximum replacement of fish meal that did not cause a significant delay in the growth of Striped snake head murrel contained 2.65 g of sulphur amino acids (SAA; methionine + cystine) / 100 g of protein or 1, 28% of the diet (0.85% of dietary methionine, dry basis). With a similar objective, but working with younger individuals, Kumari *et al.* [12] performed a cultivation with 8.3 g striped snake head murels in floating cages for eight weeks. The Juveniles were fed with isoprotein and isolipid diets (45% crude protein and 15% lipids) containing increasing soybean meal levels to replace fishmeal. At the end of the work, the authors observed that the productive performance of striped snake head murrel was not affected when up to 20% of the fish meal in the diet was substituted by soybran. This diet contained 40.0% fishmeal and 14.6% soybean meal and a 1.06% methionine level (dry basis). Through quadratic regression, the authors concluded that the optimal inclusions of fish meal and soybean meal were 40.5% and 13.5%, respectively.

Comparatively, in the present study, the formulated levels of SAA when using 45.0% of salmon flour and 24.6% of soy

bran reached 1.95% of the diet (1.33% of methionine, dry base). The regression analysis indicated an optimal inclusion of salt flour of 47.9%, substantially higher than the levels reported in the literature. The differences observed between the works by Sagada *et al.* [17], Zehra and Khan (2012) and the present study are probably the result of the source and quality of fish meal and the use of purified proteins and additives in diets. While the diets of Sagada *et al.* [18], Zehra and Khan (2012) made use of casein, choline chloride and anchovy flour, commonly produced from whole fish and with levels of crude protein between 67.8 and 70.7%, the present study used residues from the processing of farmed salmon, with a CP content of 62.8%. Daniel Lemos (personal communication) reported a degree of hydrolysis of the salmon protein crude protein at the level of the stomach and pyloric caeca of striped snake head murrel in the order of $3.66 \pm 0.31\%$ compared to a value greater than 4.0 for anchovy flour. Therefore, the differences in the optimal inclusions of fishmeal and methionine in the works are probably due to differences in the ingredients used' protein digestibility. Contrary to these observations, Katheline Hua *et al.* [11] evaluated the digestibility of protein, lipids and essential amino acids (EAA) for Juveniles of striped snake head murrel. The authors concluded that

fishmeal (Peruvian), soybean meal, viscera meal, meat and bone meal, peanut meal and canola meal have a protein and lipid digestibility greater than 87% and methionine greater than 90%.

5. CONCLUSION

This study carried out with juveniles of striped snakehead murrel between 8.2 g to 376.3±3.70 g. Under controlled experimental conditions, it was possible to conclude that the species requires practical diets with high levels of crude protein and lipids, derived mainly from flour and salmon oil, respectively. While substitutions of salmon flour protein with soybean protein were possible, the optimal ratio between the two ingredients was high, in the order of 1.8. In basal diets with 51.4% salmon flour and 16.1% soybean meal, the maximum substitutions achieved were 12%. Substitutions beyond this level, without compromising the species' performance, were only achieved when supplementing with synthetic amino acids and food mixtures with VPC or APC with an improved nutritional profile. This nutritional approach, feasible for adoption by local feed industries, showed that diets can contain up to 33.5% of salmon flour inclusion, reducing up to 17.9% the cost of formulating the feed. This is the first nutrition study carried out in India with Striped snakehead murrel jaguars using practical ingredients available in the local

market. The results point to the need for nutritional improvement of commercial rations to cultivate striped snakehead murrel.

REFERENCES

- [1] Abdul Hamid, Noor Khalidah & Mustapar, Nurul Nadiah & Hashim, Roshada & Siti-Azizah, M.. (2018). Total Replacement of Fish Meal With processed Poultry Offal Meal (P-POM) Enhances the Growth Performance and Feed Utilization in Snakehead, *Channa striata* (Bloch, 1793) Juveniles. *International Journal of Oceanography & Aquaculture*. 2. 10.23880/IJOAC-16000138.
- [2] Aliyu-Paiko, Mohammed & Hashim, Roshada & Shu-Chien, Alexander & Yogarajah, Lavineshwary & El-sayed, Abdel. (2009). Influence of different sources and levels of dietary protein and lipid on the growth, feed efficiency, muscle composition and fatty acid profile of Snakehead *Channa striata* (Bloch, 1793) fingerling. *Aquaculture Research*. 41. 1365 - 1376. 10.1111/j.1365-2109.2009.02425.x.
- [3] Annasari M, Aris WM, Yohanes K. (2012). Albumin and zinc content of snakehead fish (*Channa striata*) extract and its role in health. IEESE

- International Journal of Science and Technology. 1(2), page 1–8
- [4] Bloch ME. Natural history of the foreign fish. Berlin: Morino & Co; 1793
- [5] Dayal R, Srivastava PP, Jena J, Raizada S, Yadav AK, Bhatnagar A, Chowdhary S. (2016). Effect of various dietary fats supplementation on the liver glycogen, protein and digestive enzymes activities in striped murrel, *Channa striatus*. J App Biol Biotech. 4 (06), page 015-021. DOI: 10.7324/JABB.2016.40603
- [6] El-Haroun, Ehab & Goda, Ashraf & Chowdhury, M A Kabir. (2006). Effect of dietary probiotic Biogen, supplementation as a growth promoter on growth performance and feed utilization of Nile tilapia *Oreochromis niloticus* (L.). Aquaculture Research. 37, 1473 - 1480. 10.1111/j.1365-2109.2006.01584.x.
- [7] Hamid, S. A., Rawi, C. S., & Ahmad, A. H. (2016). Life History of *Thalerosphyrus* (Ephemeroptera: Heptageniidae) in Tropical Rivers with Reference to the Varying Altitude. *Tropical life sciences research*, 27(1), 43–62.
- [8] Haniffa, M. A., Sheela, P. A., Kavitha, K., & Jais, A. M. (2014). Salutory value of haruan, the striped snakehead *Channa striatus* - a review. *Asian Pacific journal of tropical biomedicine*, 4(Suppl 1), S8–S15. <https://doi.org/10.12980/APJTB.4.2014C1015>
- [9] Hien, Thanh & Be, Tran & Lee, Chong & Bengtson, David. (2015). Development of formulated diets for snakehead (*Channa striata* & *Channa micropeltes*): Can phytase and taurine supplementation increase use of soybean meal to replace fish meal? *Aquaculture*. 448. 10.1016/j.aquaculture.2015.06.020.
- [10] Hien, Thanh & Tran Minh, Phu & Tu, Tran & Nguyen, Tien & Pham Minh, Duc & Bengtson, David. (2016). Effects of replacing fish meal with soya protein concentrate on growth, feed efficiency and digestibility in diets for snakehead, *Channa striata*. *Aquaculture Research*. 10.1111/are.13147.
- [11] Katheline Hua, Wolfgang Koppe, Ramon Fontanillas, (2018), Effects of dietary protein and lipid levels on growth, body composition and nutrient utilization of *Channa striata*, *Aquaculture*, 10.1016/j.aquaculture.2018.11.054,
- [12] Kumari, Sangeeta & Tiwari, V. & Kumar, Rajesh & Rani, Babitha & Prakash, Satya. (2018). Effect of

- feeding rate on growth, survival and cannibalism in striped snakehead, *Channa striata* (Bloch, 1793) Juveniles. *Journal of Experimental Zoology India*. 21, page 205-210.
- [13] Lee, Y.J.; Yoon, W.B. (2015) Flow behavior and hopper design for black soybean powders by particle size. *J. Food Eng.*, 144, 10–19
- [14] Munir, M. B., Hashim, R., Abdul Manaf, M. S., & Nor, S. A. (2016). Dietary Prebiotics and Probiotics Influence the Growth Performance, Feed Utilisation, and Body Indices of Snakehead (*Channa striata*) Juveniles. *Tropical life sciences research*, 27(2), 111–125.
- [15] National Research Council (NRC) (2011) National Academy Press; Washington DC, USA: Nutrient requirements of fish and shrimp.
- [16] Paul B.N. et al., (2018), Nutrient Profile of Five Freshwater Fish Species, SAARC J. Agri., 16(2): 25-41.
DOI:<https://doi.org/10.3329/sja.v16i2.40256>
- [17] Sagada, G., Chen, J., Shen, B., Huang, A., Sun, L., Jiang, J., & Jin, C. (2017). Optimizing protein and lipid levels in practical diet for juvenile northern snakehead fish (*Channaargus*). *Animal nutrition* 3(2), 156–163.
- [18] Sagada, Gladstone & Chen, Jianming & Shen, Binqian & Huang, Aixia & Sun, Lihui & Jiang, Jianhu & Jin, Chunhua. (2017). Optimizing Protein and Lipid Levels in Practical Diet for Juvenile Northern Snakehead Fish (*Channaargus*). *Animal Nutrition*. 3. 10.1016/j.aninu.2017.03.003.
- [19] Samantaray K., Mohanty S.S. (1997), Interactions of dietary levels of protein and energy on fingerling snakehead, *Channa striata*. *Aquaculture*. 156, page 241–324
- [20] Srivastava, S. (1980). Seasonal histological changes in the ovary of a freshwater large murrel. *Channamarulius* (Ham): *Zool. J. fuer. Anat.*, 4, page 492-499.
- [21] Thuy-Yen Duong, Sophorn Uy, Phen Chheng, Nam So, Thanh-Hien Thi Tran, Ngoc-Tran Thi, Robert Pomeroy, Hillary Egna, (2019) Genetic diversity and structure of striped snakehead (*Channa striata*) in the Lower Mekong Basin: Implications for aquaculture and fisheries management, *Fisheries Research*, 10.1016/j.fishres, 218, page 166-173
- [22] Tran Thi Thanh Hien, Tran Minh Phu, Tran Le Cam Tu, Nguyen Vinh Tien, Pham Minh Duc, David A, (2017), Effects of replacing fish meal with soya protein concentrate on

- growth, feed efficiency and digestibility in diets for snakehead, *Channa striata*, 48 (6), Pages 3174-3181
- [23] White, J. & Hart, R. Fry. J, (1980) Na Evaluation of the Waters Pico-Tag System for the Amino-Acid-Analysis of Food Materials. Journal of Automatic Chemisty. 8(4), p. 170-177
- [24] Yu Wu, Horst Kaiser, Clifford L. W. Jones, (2018), A first study on the effect of dietary soya levels and crystalline isoflavones on growth, gonad development and gonad histology of farmed abalone, Haliotismidae, *Aquaculture International*. 10.1007/s10499-018-0315-6.
- [25] Zehra, S. Khan, M.A. (2012) "Dietary protein requirement for fingerling *Channa punctatus* (Bloch) based on growth, feed conversion, protein retention and biochemical composition, *AquacultInt*, 20, pp. 383-395