

# Nutritional Value and Apparent Digestibility for Dry Matter, Protein, Energy and Essential Amino Acid in Ten Selected Feedstuffs for Juvenile *Penaeus monodon*

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## Abstract

Nutritional values and apparent digestibility coefficients for dry matter (ADMD), protein (APD), energy (AED) and amino acid (AAAD) of ten feedstuffs were determined for juvenile shrimp, which included Peruvian steam fish meal, Peruvian FAQ fish meal, local fish meal, soybean meal, peanut meal, shrimp head meal, cottonseed meal, rapeseed meal, wheat flour and brewer's yeast. A reference diet and test diets that consisted of a 70:30 mixture of the reference diet to test feedstuff were used with 0.01% Yttrium oxide as an external marker. The eleven diets were fed to triplicate groups of juvenile *Penaeus monodon* (mean initial weight 1.13 g ± 0.02 g) for 56 days. After the 56-day trial, the highest and lowest values of weight gain (WG) and specific growth rate (SGR) of shrimp were found in shrimp head meal and cottonseed meal diet treatments, respectively. Feed conversion ratio (FCR) was in the range of 1.25-1.65. Peruvian steam fish meal and shrimp head meal diet treatments had the lowest FCR and cottonseed meal and rapeseed meal diet treatments had the highest FCR. The ADMD of diets is in the range of 63.52% to 80.07%. The values of ADMD in shrimp head meal and wheat flour diets (77.58% and 80.07%) were significantly higher than that in other diets ( $P < 0.05$ ). APD, AAAD and AED differed greatly among feedstuffs, from 82.2% to 110.5%, 88.26% to 103.37% and 64.5% to 97.6%, respectively. ADMD for the shrimp head meal, Peruvian FAQ fish meal and wheat flour were excellent (over 90%), while brewer's yeast had lowest value of ADMD (under 60.52%). Peanut meal, cottonseed meal, rapeseed meal and brewer's yeast had the lowest average AAAD (~90%). The average AAAD of Peruvian steam fish meal, Peruvian FAQ fish meal, local fish meal, soybean meal and shrimp head meal were nearly similar (95% to 99%). Wheat flour had the highest average AAAD (106%). In terms of ADMD, the most digestible ingredients were, in descending order, shrimp head meal, Peruvian FAQ fish meal, Peruvian steam fish meal, local fish meal for the marine feedstuffs; soybean meal and wheat flour are more preferable for *P. monodon* feed compared to other plant feedstuffs such as peanut meal, cottonseed meal and rapeseed meal.

**Keywords:** *Penaeus monodon*; Feedstuffs; Growth; Apparent digestibility coefficient

## Introduction

Fish meal has been the most important feedstuff used as a source of protein in aquaculture feeds because of its essential amino acid composition and palatability [1]. Demand for protein ingredients in aquaculture is expected to exceed supply in the next decade. The sustainability of this sector depends, therefore, largely on the development of more cost-effective compounded feeds that rely less on costly protein sources such as fish meal. From an economical point of view, it is beneficial to use low-cost protein sources. The current trend is to decrease fish meal in aqua feeds and this has generated research for finding suitable alternative protein sources [2-8]. Although considerable progress has been made, most raw materials are deficient in one or more of the ten essential amino acids, especially methionine, the first limiting essential amino acid in plant and rendered animal byproducts. Protein and amino acids are considered expensive nutrients in feeds, and an oversupply of crude protein is the main cause of nitrogen contamination of pond water and environmental pollution [9]. Reduction in the dietary protein content without depressing amino acid requirements of shrimp can reduce feed costs and nitrogen pollution. Information on amino acid requirements and utilization in shrimp is undoubtedly one of the main issues limiting the development of shrimp feeding industry.

Despite accumulating evidences that free amino acids are utilized efficiently by fish and shrimp [2,5,10,11], leaching of nutrients and

in particular of amino acids and other nitrogen-compounds is long recognized to lead to eutrophication of the water, thus negative impacting the environment. Diets have been usually evaluated in terms of growth with little attention to the digestibility. Generally, shrimp diets are formulated in terms of crude protein and amino acids content without considering the bioavailability of these ingredients. A feed may contain the adequate amount of nutrients formulated for a species but will just be wasted and detrimental to the environment if not efficiently assimilated. An effective feed can be prepared when information on digestibility of nutrients in feedstuffs has been considered in its formulation [12]. Thus, assessing the digestibility is the first step in evaluating the potential of a feedstuff for use in the diet of reared species [13]. Digestibility trials evaluate the nutritional value of a feedstuff which provides important information in growth measurements [14].

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In China, traditional tiger shrimp, *Penaeus monodon* diets are typically comprised of Peruvian fish meal, soybean meal, peanut meal, wheat flour, brewer's yeast, shrimp head meal and vitamin and mineral supplements. Recently, with increasing prices of traditional feed ingredients, such as Peruvian fish meal and soybean meal, more alternative feedstuffs, such as local fish meal, cottonseed meal, rapeseed meal, are being used to partially replace high cost, traditional ingredients in tiger shrimp diets. Moreover, previous studies mainly focused on nutrient digestibility for shrimp have only reported values for crude protein and dry matter [15-18]. Data on amino acid digestive utilization coefficients is one of the most important factors in preparing adequate shrimp feeds and there is an increasing interest in defining feedstuff quality using as criterion the coefficients of amino acid digestibility [19-21]. Hence, creating a database of digestibility of amino acids could provide more useful, accurate, and flexible information for low cost formulation processes. However, digestibility studies of amino acids of these alternative ingredients and traditional feed ingredients are deficient for tiger shrimp, *P. monodon*. The purpose of this study was to determine the growth and apparent digestibility coefficients (ADCs) of dry matter, crude protein, energy and essential amino acids in feedstuffs used in diets for tiger shrimp, *P. monodon*.

## Methods and Materials

### Feedstuffs

A digestibility trial was conducted to determine the apparent digestibility coefficients of dry matter (ADMD), protein (APD), energy (AED) and amino acids (AAAD) for ten feed ingredients. These included three commercial fish meals; Peruvian steam fish meal; Peruvian FAQ fish meal; local fish meal; soybean meal; peanut meal; shrimp head meal; cottonseed meal; rapeseed meal; wheat flour; brewer's yeast. Peruvian steam fish meal, Peruvian FAQ fish meal, local fish meal and shrimp head meal were supplied by FOSHAN SHUNDE LIBAO Feed Co., LTD, P.R. China. Soybean meal, peanut meal, cottonseed meal, rapeseed meal, wheat flour and brewer's yeast were supplied by FOSHAN SHUNDE Feed Industrial Co., LTD, P.R. China. All the tested ingredients were cooked with a temperature at 92°C, steam pressure of 140 PSI and with a 120-second retention time before we got it.

### Formulation and diet preparation

A reference diet (Table 1) was formulated to contain ~41% crude protein and ~7% lipids. A reference diet and test diets that consisted of a 70:30 mixture of the reference diet to test feedstuff were used with 0.01% Yttrium oxide as an external indicator. Table 2 lists the nutritional composition (dry matter, crude protein, crude lipid, gross energy, ash and gross phosphorus) of the test feedstuffs. Table 3 lists the proximate composition and amino acid content of the diets. Prior to preparing the diets, feed ingredients were pulverized and sieved (250 µm). The dry ingredients of each diet were mixed thoroughly in a food mixer before soya lecithin, soybean oil and fish oil was added. After the oil was dispersed, water was added (approximately 40% of the total "as is" ingredient weight) and mixed. The resulting mixture was pelleted with a meat grinder and a 1.2 mm diameter die (Institute of Chemical Engineering, South China University of Technology, Guangzhou, P.R. China). The diets were dried in an oven at 60°C for 10 h and then the resulting pellets were dried at 25°C with the aid of air conditioner and an electrical fan until moisture was reduced to less than 10%. The dry pellets were placed in plastic bags and stored -20°C until used.

## Shrimp and experimental set up

Juvenile *P. monodon* were obtained from a semi-intensive culture pond near Hongsha Bay, Sanya, Hainan province, China. Shrimp were acclimated to the experimental conditions and fed a commercial feed (~41% crude protein) without yttrium oxide for 2 weeks before the experiment started. A total of 1320 shrimp with an initial body weight of 1.14 g ± 0.03 g were distributed randomly into 33 fiberglass tanks (500L, 0.5 m<sup>2</sup> bottom, 3 tanks per diet, 40 shrimp per tank). Water exchange in each tank was adjusted to approximately 1.0 L/min with a flowing sand filtered water system (the thickness of the sand in the sand filter is 100cm). Each tank was covered by a plastic mesh lid to prevent shrimp from jumping out. The shrimp were cultured outdoors with a steel awning and subjected to a natural photoperiod. During the experimental period, the water temperature, salinity, dissolved oxygen and total ammonia nitrogen ranged from 26.8°C to 27.9°C, 29.0 g L<sup>-1</sup> to 31.0 g L<sup>-1</sup>, 6.5 g L<sup>-1</sup> to 7.5 mg L<sup>-1</sup> and 0.2 g L<sup>-1</sup> to 0.3 mg L<sup>-1</sup>, respectively.

All shrimp in each tank were initially fed 6% of total body weight daily. The feeding frequency was three times per day at 7:00, 13:00, and 21:00 h and lasted for 56 days. During the feeding trial, the amount of diet given was progressively changed and adjusted according to the appetite of the shrimp by checking the bottom of the tanks for excess feed remaining 2 h after feeding. This way overfeeding was minimized and shrimp were fed close to satiation. Every morning and afternoon before each feeding time, all residual/uneaten feed, faeces, and moults and dead shrimp were siphoned from tanks. Uneaten feed particles were dried and weighed and used for correction of feed intake. After 56 days of the breeding trial, feces started to be collected two times daily (8:00 and 14:00), approximately one hour after each feeding by gently

Ingredients	
Fish meal	35
Soybean meal	14
Peanut meal	13.39
Wheat flour	20
Brewer's yeast	5
Shrimp head meal	5
Soya lecithin	1
Fish oil	1
Soybean oil	1
Choline chloride (50%)	0.5
Ca(H <sub>2</sub> PO <sub>4</sub> ) <sub>2</sub> ·H <sub>2</sub> O	1
Vitamin premix*	1
Mineral premix†	1
Sodium alginate	1
Ascorbic phosphate ester	0.1
Y <sub>2</sub> O <sub>3</sub>	0.01
Nutrient levels‡	
Moisture	6.08
Crude protein	41.01
Crude lipid	7.27
Ash	12.77

\*Vitamin premix (%): VD<sub>3</sub> 0.06 M.I.U., VB<sub>1</sub> 0.36 g, VB<sub>2</sub> 0.72 g, VB<sub>6</sub> 0.66 g, VB<sub>12</sub> 0.002 g, VE 1.65 g, VK<sub>3</sub> 0.24 g, VB<sub>3</sub> 1.44 g, VB<sub>5</sub> 0.4 g, biotin 0.002 g, folic acid 0.12 g, inositol 3 g, Vc 10 g, cellulose was used as a carrier.  
 † Vitamin premix (%): P 12 g, Ca 12 g, Mg 1.5 g, Fe 0.15 g, Zn 0.42 g, Cu 0.21 g, K 7.5 g, Co 0.011 g, Mn 0.16 g, Se 0.001 g, Mo 0.0005 g, Al 0.0025 g, I 0.04 g, cellulose was used as a carrier.  
 ‡ Measured values.

**Table 1:** Ingredient composition and nutrients levels (% dry matter) of the reference diet used for the digestibility trial.

Test feedstuffs	Day matter (%)	Crude protein (%)	Crude lipid (%)	Gross energy (kJ g <sup>-1</sup> )	Ash (%)	Gross phosphorus (%)
Peruvian steam fish meal	92.08	70.91	10.29	21.80	13.50	2.24
Peruvian FAQ fish meal	93.89	69.44	8.89	20.50	14.29	2.88
Local Fish meal	91.58	69.77	10.00	19.70	17.79	2.69
Soybean meal	90.93	50.01	1.80	19.30	4.26	0.75
Peanut meal	90.04	55.37	5.02	19.00	5.25	0.89
Shrimp head meal	90.15	42.08	1.01	12.80	22.66	1.28
Cottonseed meal	93.71	44.13	1.20	19.00	5.01	1.26
Rapeseed meal	92.59	41.94	1.71	19.50	6.93	1.17
Wheat flour	90.88	18.28	0.70	17.80	1.22	0.30
Brewer's yeast	91.70	44.40	0.68	17.68	6.47	1.20

Table 2: Nutritional composition of test ingredients.

Nutrients	Test diets (a 70 : 30 mixture of the reference diet to test feedstuffs)										
	Reference diet	Peruvian steam fish meal	Peruvian FAQ fish meal	Local fish meal	Soybean meal	Peanut meal	Shrimp head meal	Cottonseed meal	Rapeseed meal	Wheat flour	Brewers yeast
Dry matter	93.92	94.04	94.04	94.09	93.85	94.06	93.9	93.72	93.36	93.57	93.81
protein	41.01	48.63	48.32	48.28	43.82	45.54	41.26	41.54	41.09	33.23	41.99
Lipid	7.27	7.97	7.29	6.64	5.24	6.53	4.34	5.52	5.85	5.13	5.82
Ash	12.77	13.86	13.57	18.72	10.09	10.51	20.13	10.41	10.73	9.26	10.62
GE(KJg <sup>-1</sup> ) *	16.43	16.35	18.15	17.11	18.8	17.99	16.46	18.31	18.02	15.04	15.5
Amino acids											
Lysine	2.25	2.93	3.07	2.89	2.64	2.64	2.52	2.4	2.28	2.27	2.68
Phenylalanine	1.53	1.63	1.71	1.62	1.77	1.79	1.43	1.73	1.57	1.54	1.67
Methionine	0.85	0.88	0.88	0.87	0.82	0.84	0.84	0.79	0.78	0.78	0.88
Cysteine †	0.21	0.26	0.26	0.26	0.25	0.25	0.24	0.23	0.22	0.22	0.24
Threonine	1.38	1.59	1.64	1.53	1.5	1.46	1.39	1.33	1.39	1.28	1.67
Isoleucine	1.83	2.02	2.1	1.98	2.04	1.88	1.76	1.78	1.57	1.56	2.02
Valine	2.01	2.2	2.31	2.17	2.19	2.17	1.91	2.07	1.98	1.94	2.28
Leucine	2.76	3.11	3.24	3.02	3.33	2.99	2.59	2.72	2.6	2.54	3.01
Histidine	0.97	1.12	1.18	1.11	1.02	1	0.84	1.01	0.98	0.94	1
Arginine	2.43	2.73	2.77	2.73	2.71	3.3	2.38	3.08	2.58	2.56	2.36
DMWS ‡	9.34 ± 0.06	9.37 ± 0.12	9.29 ± 0.06	9.40 ± 0.09	9.36 ± 0.13	9.46 ± 0.03	9.52 ± 0.05	9.50 ± 0.08	9.39 ± 0.05	9.47 ± 0.03	9.36 ± 0.17

\*Gross energy † Non-essential ‡ Dry matter water stability

Table 3: Proximate composition (% dry matter), essential amino acid content (% diet) and dry matter water stability in seawater at 27°C for 1 hour (% ± SD) of the reference and test diets.

siphoning fecal strands with a Pasteur pipette. If present, uneaten feed particles which were dyed red were easily sorted from the feces strands and discarded. Feces were gently rinsed with distilled water, transferred to 30 ml conic tubes, and frozen at -20°C. Daily samples of frozen fecal material corresponding to each tank were pooled, freeze-dried, ground, thoroughly mixed, and kept frozen at -80°C until analyzed. Sample collections were accumulated until 1.5 g dry weight of fecal material (~15 g wet feces) from each tank had been collected.

### Sampling and chemical analysis

Samples of the test ingredients and test diets were finely ground and sieved before chemical analysis. Moisture, crude protein, crude lipid and crude ash of the diets and feces were determined using standard methods [22]. Moisture was determined by oven drying at 105°C for 24 h, and ash was determined using a muffle furnace at 550°C for 24 h. Crude protein was analyzed by the Kjeldahl method after acid digestion (1030-Auto-analyzer, Tecator, Sweden). Crude lipid was determined by the ether-extraction method by Soxtec System HT (Soxtec System HT6, Tecator). Energy of the diets and fecal material were determined by an adiabatic micro-bomb calorimeter (HR-15A

adiabatic calorimeter, Changshan, China). Yttrium (Y) was analyzed using inductivity couple plasma mass spectroscopy (ICP; model: IRIS Advantage (HR), Thermo Jarrel Ash Corporation, Boston, USA) [23]. The amino acid composition of all samples were analyzed following acid hydrolysis using an automatic amino acid analyzer (Hitachi 835-50, Japan) with a column (Hitachi custom ion exchange resin no. 2619) by Evonik Degussa (China) Co.Ltd. Novel product, Evonik Degussa GmbH. In brief, performic acid oxidation was performed prior to hydrolysis to oxidize cystine and methionine to cysteic acid and methionine sulfone. Then sodium metabisulfite was added to decompose surplus performic acid. Subsequently, amino acids were liberated from protein by hydrolysis with 6 N HCl. Hydrolysed samples were diluted with sodium citrate buffer, pH was adjusted to 2.2, and individual amino acid components were separated by ion exchange chromatography at 570 nm. Tryptophan was not determined.

### Calculations and statistical analysis

Biological parameters used to evaluate the quality of diets were calculated by equations as follows:

$$\text{Weight gain (WG) (\%)} = 100 \times (W_f - W_i) / W_i$$

$$\text{Specific growth rate (SGR) (\% day}^{-1}\text{)} = 100 \times (\ln W_f - \ln W_i) / t$$

$$\text{Survival (\%)} = 100 \times N_f / N_0$$

$$\text{Feed conversion ratio (FCR)} = \text{dry feed intake} / (W_f - W_0)$$

$$\text{ADC} = [1 - (Y_f/Y_p) \times (N_f/N_i)]$$

Where  $W_f$  and  $W_i$  were mean final and initial shrimp body weights;  $t$  is the experimental duration in days;  $N_f$  is number of shrimp at the end of the trials and  $N_0$  at the start;  $W_f$  (g) is total final body weight and  $W_0$  (g) total initial body weight;  $Y_f$  is trioxide yttrium content in feed;  $Y_p$  is trioxide yttrium content in feces;  $N_i$  is nutrient content in feed;  $N_f$  is nutrient content in feces.

All data are presented as means  $\pm$  S.E.M. and subjected to one-way analysis of variance (ANOVA) to test the effects of experimental diets using the software of the SPSS for windows (ver 16.0, U.A.S). Duncan's new multiple range test was used to resolve the differences among treatment means [24]. Statistical significance was examined at  $P < 0.05$  unless otherwise noted.

## Results

### Growth performance

Growth performance of *P. monodon* presented in Table 4 were significantly affected by dietary treatments ( $P < 0.05$ ). Survival was in the range of 47.78% to 77.78%, the highest and lowest values of survival of shrimp were found in shrimp head meal and cottonseed meal diet treatments, respectively ( $P < 0.05$ ); moreover, survival of shrimp in cottonseed meal diet treatment was significantly lower than that of shrimp in reference diet, Peruvian steam fish meal, shrimp head meal

and brewer's yeast diet treatments ( $P < 0.05$ ) but without significant difference with other diet treatments ( $P > 0.05$ ). The highest and lowest values of WG of shrimp were found in shrimp head meal and cottonseed meal diet treatments, respectively ( $P < 0.05$ ); moreover, WG of shrimp in Peruvian steam fish meal was significantly higher than that of shrimp in reference diet treatment ( $P < 0.05$ ), and WG of shrimp in local fish meal and brewer's yeast diet treatments were significantly lower than that of shrimp in shrimp head meal diet treatment and higher than that of shrimp in other diet treatments except for local fish meal and brewer's yeast diet treatments; WG of shrimp in soybean meal diet treatment was significantly higher than that of shrimp in peanut meal, rapeseed meal and wheat flour diet treatments ( $P < 0.05$ ) but no significant difference was found in WG among peanut meal, rapeseed meal and wheat flour diet treatments ( $P > 0.05$ ). SGR had the similar tendency with WG. FCR was in the range of 1.25-1.65. Cottonseed meal and rapeseed meal diet treatments had the highest FCR, followed by peanut meal, wheat flour, soybean meal, Peruvian FAQ fish meal, reference diet, brewer's yeast and local fish meal diet treatments, and finally the Peruvian steam fish meal and shrimp head meal diet treatments.

### Apparent digestibility coefficients (ADC, %) for dry matter, crude protein, amino acid and energy in reference diet and test diets

The ADMD, APD, AAAD and AED of reference diet and test diets consumed by *P. monodon* are shown in Table 5. The ADMD of diets is in the range of 63.52% to 80.07%. The ADMD of shrimp head meal and wheat flour diets (77.58% and 80.07%) were significantly higher than that of other diets ( $P < 0.05$ ). The ADMD of brewer's yeast diet (63.52%)

Items	Initial mean weight/g	Final mean weight/g	Survival/%	WG/%	SGR/(%/d)	FCR
Reference diet	1.12 $\pm$ 0.02	7.45 $\pm$ 0.40 <sup>e</sup>	70.56 $\pm$ 5.71 <sup>bc</sup>	563.04 $\pm$ 35.48 <sup>e</sup>	3.15 $\pm$ 0.09 <sup>e</sup>	1.36 $\pm$ 0.03 <sup>bc</sup>
Peruvian steam fish meal	1.15 $\pm$ 0.01	8.48 $\pm$ 0.17 <sup>h</sup>	70.00 $\pm$ 6.67 <sup>bc</sup>	639.45 $\pm$ 21.80 <sup>f</sup>	3.33 $\pm$ 0.05 <sup>f</sup>	1.29 $\pm$ 0.04 <sup>ab</sup>
Peruvian FAQ fish meal	1.12 $\pm$ 0.01	6.04 $\pm$ 0.13 <sup>c</sup>	53.33 $\pm$ 10.00 <sup>ab</sup>	441.38 $\pm$ 14.91 <sup>c</sup>	2.81 $\pm$ 0.05 <sup>c</sup>	1.40 $\pm$ 0.04 <sup>cd</sup>
Local fish meal	1.12 $\pm$ 0.03	7.75 $\pm$ 0.24 <sup>ef</sup>	57.78 $\pm$ 11.71 <sup>ab</sup>	595.50 $\pm$ 14.70 <sup>ef</sup>	3.23 $\pm$ 0.04 <sup>ef</sup>	1.33 $\pm$ 0.04 <sup>bc</sup>
Soybean meal	1.11 $\pm$ 0.01	6.65 $\pm$ 0.15 <sup>d</sup>	63.33 $\pm$ 8.82 <sup>abc</sup>	497.63 $\pm$ 9.58 <sup>d</sup>	2.98 $\pm$ 0.03 <sup>d</sup>	1.44 $\pm$ 0.04 <sup>de</sup>
Peanut meal	1.12 $\pm$ 0.01	4.84 $\pm$ 0.12 <sup>ab</sup>	62.22 $\pm$ 13.47 <sup>abc</sup>	331.53 $\pm$ 8.73 <sup>ab</sup>	2.44 $\pm$ 0.03 <sup>b</sup>	1.49 $\pm$ 0.04 <sup>e</sup>
Shrimp head meal	1.15 $\pm$ 0.03	9.79 $\pm$ 0.74 <sup>i</sup>	77.78 $\pm$ 5.09 <sup>c</sup>	755.93 $\pm$ 79.94 <sup>g</sup>	3.57 $\pm$ 0.15 <sup>g</sup>	1.25 $\pm$ 0.03 <sup>a</sup>
Cottonseed meal	1.13 $\pm$ 0.03	4.36 $\pm$ 0.19 <sup>a</sup>	47.78 $\pm$ 11.71 <sup>a</sup>	287.32 $\pm$ 8.54 <sup>a</sup>	2.26 $\pm$ 0.04 <sup>a</sup>	1.65 $\pm$ 0.04 <sup>f</sup>
Rapeseed meal	1.13 $\pm$ 0.03	5.02 $\pm$ 0.08 <sup>b</sup>	53.33 $\pm$ 3.33 <sup>ab</sup>	330.67 $\pm$ 12.66 <sup>ab</sup>	2.43 $\pm$ 0.05 <sup>b</sup>	1.61 $\pm$ 0.04 <sup>f</sup>
Wheat flour	1.13 $\pm$ 0.02	5.18 $\pm$ 0.09 <sup>b</sup>	61.11 $\pm$ 12.62 <sup>abc</sup>	349.82 $\pm$ 1.41 <sup>b</sup>	2.51 $\pm$ 0.01 <sup>b</sup>	1.45 $\pm$ 0.05 <sup>de</sup>
Brewer's yeast	1.13 $\pm$ 0.02	8.19 $\pm$ 0.19 <sup>g</sup>	72.22 $\pm$ 10.72 <sup>bc</sup>	594.20 $\pm$ 17.46 <sup>ef</sup>	3.23 $\pm$ 0.04 <sup>ef</sup>	1.34 $\pm$ 0.06 <sup>bc</sup>

In the same row, values with different small letter superscripts mean significant difference ( $P < 0.05$ ).

Table 4: Growth performance of *P. monodon* fed with reference and test diets.

Items	Dry matter	Protein	Amino acid	Energy
Reference diet	64.80 $\pm$ 2.49 <sup>ab</sup>	83.84 $\pm$ 1.71 <sup>ab</sup>	93.44 $\pm$ 0.46 <sup>cd</sup>	83.11 $\pm$ 0.93 <sup>cd</sup>
Peruvian steam fish meal	69.12 $\pm$ 1.89 <sup>cd</sup>	86.26 $\pm$ 0.81 <sup>c</sup>	94.42 $\pm$ 0.34 <sup>ef</sup>	82.82 $\pm$ 0.85 <sup>bcd</sup>
Peruvian FAQ fish meal	72.92 $\pm$ 1.68 <sup>e</sup>	87.97 $\pm$ 0.70 <sup>d</sup>	94.22 $\pm$ 0.36 <sup>ef</sup>	88.13 $\pm$ 0.71 <sup>f</sup>
Local Fish meal	67.74 $\pm$ 2.10 <sup>bc</sup>	86.11 $\pm$ 0.90 <sup>c</sup>	93.84 $\pm$ 0.40 <sup>de</sup>	84.45 $\pm$ 0.63 <sup>de</sup>
Soybean meal	71.40 $\pm$ 2.68 <sup>de</sup>	88.47 $\pm$ 0.63 <sup>d</sup>	95.11 $\pm$ 0.46 <sup>gh</sup>	83.38 $\pm$ 1.64 <sup>cd</sup>
Peanut meal	65.85 $\pm$ 2.39 <sup>ab</sup>	84.83 $\pm$ 1.15 <sup>bc</sup>	92.84 $\pm$ 0.50 <sup>bc</sup>	82.55 $\pm$ 1.01 <sup>bc</sup>
Shrimp head meal	77.58 $\pm$ 0.96 <sup>f</sup>	88.70 $\pm$ 0.41 <sup>d</sup>	95.24 $\pm$ 0.21 <sup>h</sup>	85.26 $\pm$ 0.36 <sup>e</sup>
Cottonseed meal	71.56 $\pm$ 0.91 <sup>de</sup>	85.49 $\pm$ 0.31 <sup>c</sup>	92.58 $\pm$ 0.24 <sup>b</sup>	81.23 $\pm$ 1.24 <sup>b</sup>
Rapeseed meal	67.89 $\pm$ 1.14 <sup>bc</sup>	85.55 $\pm$ 0.38 <sup>c</sup>	92.88 $\pm$ 0.25 <sup>bc</sup>	81.71 $\pm$ 0.66 <sup>bc</sup>
Wheat flour	80.07 $\pm$ 0.40 <sup>f</sup>	87.71 $\pm$ 0.55 <sup>d</sup>	94.56 $\pm$ 0.11 <sup>g</sup>	86.93 $\pm$ 0.25 <sup>f</sup>
Brewer's yeast	63.52 $\pm$ 0.62 <sup>a</sup>	83.33 $\pm$ 0.21 <sup>a</sup>	91.76 $\pm$ 0.14 <sup>a</sup>	76.89 $\pm$ 0.71 <sup>a</sup>

In the same row, values with different small letter superscripts mean significant difference ( $P < 0.05$ ).

\*Including lysine, phenylalanine, methionine, cysteine, threonine, isoleucine, valine, leucine, histidine, arginine.

Table 5: Apparent digestibility coefficients (ADC, %) for dry matter, crude protein, amino acid\* and gross energy in the reference and test diets consumed by *P. monodon*.

was significantly lower than that of wheat flour (80.07%), shrimp head meal (77.58%), Peruvian FAQ fish meal (72.92%), cottonseed meal (71.56%), soybean meal (71.40%), Peruvian steam fish meal (69.12%), rapeseed meal (67.89%) and local fish meal (67.74%) diets ( $P < 0.05$ ) but without significantly difference with peanut meal (65.85%) and reference diets (64.80%) ( $P > 0.05$ ). The APD of diets varied from 83.33% to 88.70%. The highest values of APD were shrimp head meal (88.70%), soybean meal (88.47%), Peruvian FAQ fish meal (87.97%) and wheat flour (87.71%) diets, followed by Peruvian steam fish meal (86.26%), local fish meal (86.11%), rapeseed meal (85.55%), cottonseed meal (85.49%) and peanut meal (84.83%) diets, and finally the brewer's yeast (83.33%) and reference (83.84%) diets. The AAAD of diets varied from 91.76% to 95.24%. The highest values of AAAD were shrimp head meal (95.24%) and soybean meal (95.11%) diets, and the lowest value of AAAD was brewer's yeast (91.76%) diet. The AED of diets varied from 76.89% to 88.13%. The highest values of AED were Peruvian FAQ fish meal (88.13%) and wheat flour (86.93%) diets, and the lowest value of AED was brewer's yeast (76.89%) diet.

#### Apparent digestibility coefficients (ADC, %) for dry matter, crude protein, amino acid and energy in test feedstuffs

The ADMD, APD, AAAD and AED in feedstuffs consumed by *P. monodon* are shown in Table 6. The ADMD of test feedstuffs varied from 60.52% to 115.71%. The highest values of ADMD were wheat flour (115.71%) and shrimp head meal (107.40%), and the lowest value of ADMD was brewer's yeast (60.52%). The ADMD of Peruvian steam fish meal (79.19%) was significantly lower than that of wheat flour (115.71%), shrimp head meal (107.40%) and Peruvian FAQ fish meal (91.87%) and higher than that of peanut meal (68.30%) and brewer's yeast (60.52%) ( $P < 0.05$ ) but without difference with cottonseed meal (87.31%), soybean meal (86.80%), rapeseed meal (75.09%) and local fish meal (74.60%) ( $P > 0.05$ ). The APD of test feedstuffs varied from 82.18% to 110.46%. The highest values of APD were wheat flour (110.46%) and shrimp head meal (107.36%), and the lowest value of APD was brewer's yeast (82.18%). The APD of Peruvian steam fish meal (90.01%) was significantly lower than that of wheat flour (110.46%), shrimp head meal (107.36%), soybean meal (98.85%) and Peruvian FAQ fish meal (94.49%) and higher than that of brewer's yeast (82.18%) ( $P < 0.05$ ) but without difference with rapeseed meal (90.76%), local fish meal (89.69%), cottonseed meal (89.36%) and peanut meal (86.78%) ( $P > 0.05$ ). The AAAD of the test feedstuffs had the similar tendency with the APD. The AED of test feedstuffs varied from 64.51% to 97.62%. The highest values of AED were Peruvian FAQ fish meal (97.62%), wheat flour (94.70%) and shrimp head meal (91.57%), and the lowest values of AED was brewer's yeast (64.51%). The AED of Peruvian steam fish meal (90.01%) was significantly lower than that of Peruvian FAQ fish meal (97.62%), wheat flour (94.70%), shrimp

head meal (91.57%) and local fish meal (87.03%) and higher than that of brewer's yeast (64.51%) ( $P < 0.05$ ) but without significant difference with soybean meal (83.90%), peanut meal (81.50%), rapeseed meal (78.97%) and cottonseed meal (77.46%) ( $P > 0.05$ ).

#### Apparent digestibility coefficients (ADC, %) of amino acids in test feedstuffs consumed by *P. monodon*

The AAAD in feedstuffs consumed by *P. monodon* are shown in Table 7. In general, amino acid availability reflected protein digestibility. The values of AAAD of the ten feedstuffs ranged from 89.35% for lysine in cottonseed meal to 102.38% in wheat flour meal. Peanut meal, cottonseed meal, rapeseed meal and brewer's yeast had the lower average AAAD (~90%). The average AAAD of Peruvian steam fish meal, Peruvian FAQ fish meal, local fish meal, soybean meal and shrimp head meal were similar (95% to 99%). Wheat flour had the highest average AAAD (106%). There were significant differences among individual amino acids. For example, digestibility of methionine was low in rapeseed meal (82.75%) and high in shrimp head meal (97.25%) and wheat flour (104.25%); there were major differences between shrimp head meal and brewer's yeast in cysteine digestibility (103.45% and 85.27%, respectively). Phenylalanine was the less digestible in brewer's yeast, whereas lysine was the lowest in cottonseed meal and rapeseed meal.

## Discussion

### Growth performance

Over the 56 days experimental period, it was observed that the diet containing shrimp head meal induced a positive feeding response. However, the diet containing cottonseed meal was not readily accepted by the shrimp. This can likely be attributed to the presence of gossypol which occurs naturally in cottonseed and was described as higher levels of dietary cottonseed meal resulted in reduced performance of shrimp [25]. The favorable response of the shrimp to Peruvian steam fish meal, local fish meal, shrimp head meal and brewer's yeast diets compare to the reference diet is probably due to the high quality of these meals in terms of both nutrient profile and possibly digestibility as well as a lack of apparent palatability problems. Digestibility data reflect the percentage of a feed feedstuff sample that is absorbed from an animal's intestinal tract [26]. Using highly digestibility feedstuffs is especially important under high-density culture conditions, where accumulations of undigested feed can foul the water, affect the growth and immunity of shrimp [27]. By comparison, the apparent digestibility of animal-based ingredient, such as fish meal and shrimp head meal. Moreover, the favorable response of brewer's yeasts is also believed to have immune stimulatory properties by virtue of their complex carbohydrate components and nucleic acid content [28]. In brewer's

Items	Dry matter	Protein	Amino acid	Energy
Peruvian steam fish meal	79.19 ± 6.29 <sup>cd</sup>	90.01 ± 2.05 <sup>b</sup>	95.83 ± 0.83 <sup>c</sup>	82.26 ± 2.48 <sup>bc</sup>
Peruvian FAQ fish meal	91.87 ± 5.62 <sup>a</sup>	94.49 ± 1.80 <sup>c</sup>	95.35 ± 0.88 <sup>c</sup>	97.62 ± 2.06 <sup>f</sup>
Local Fish meal	74.60 ± 7.01 <sup>bc</sup>	89.69 ± 2.31 <sup>b</sup>	94.41 ± 0.99 <sup>c</sup>	87.03 ± 1.85 <sup>d</sup>
Soybean meal	86.80 ± 8.95 <sup>de</sup>	98.85 ± 2.03 <sup>d</sup>	98.47 ± 1.38 <sup>d</sup>	83.90 ± 4.83 <sup>cd</sup>
Peanut meal	68.30 ± 7.95 <sup>ab</sup>	86.78 ± 3.44 <sup>b</sup>	91.63 ± 1.50 <sup>b</sup>	81.50 ± 2.92 <sup>bc</sup>
Shrimp head meal	107.40 ± 3.18 <sup>f</sup>	107.36 ± 1.49 <sup>e</sup>	101.13 ± 0.64 <sup>e</sup>	91.57 ± 1.42 <sup>e</sup>
Cottonseed meal	87.31 ± 3.02 <sup>de</sup>	89.36 ± 1.02 <sup>b</sup>	90.89 ± 0.70 <sup>b</sup>	77.46 ± 3.72 <sup>b</sup>
Rapeseed meal	75.09 ± 3.80 <sup>bc</sup>	90.76 ± 1.51 <sup>bc</sup>	91.49 ± 0.88 <sup>b</sup>	78.97 ± 1.96 <sup>b</sup>
Wheat flour	115.71 ± 1.34 <sup>f</sup>	110.46 ± 3.76 <sup>e</sup>	103.37 ± 0.98 <sup>e</sup>	94.70 ± 0.76 <sup>ef</sup>
Brewer's yeast	60.52 ± 2.06 <sup>a</sup>	82.18 ± 0.67 <sup>a</sup>	88.26 ± 0.43 <sup>a</sup>	64.51 ± 2.12 <sup>a</sup>

In the same row, values with different small letter superscripts mean significant difference ( $P < 0.05$ ).

**Table 6:** Apparent digestibility coefficients (ADC, %) for dry matter, crude protein, amino acid and energy in feedstuffs consumed by *P. monodon*.

Amino acids	Test feedstuffs									
	Peruvian steam fish meal	Peruvian FAQ fish meal	Local Fish meal	Soybean meal	Peanut meal	Shrimp head meal	Cottonseed meal	Rapeseed meal	Wheat flour	Brewers yeast
Lysine	98.76 ± 0.34 <sup>e</sup>	96.79 ± 0.45 <sup>cd</sup>	97.04 ± 0.47 <sup>d</sup>	98.39 ± 0.81 <sup>e</sup>	91.12 ± 1.50 <sup>b</sup>	98.94 ± 0.33 <sup>c</sup>	89.35 ± 0.65 <sup>a</sup>	89.40 ± 0.68 <sup>a</sup>	102.38 ± 1.07 <sup>f</sup>	95.55 ± 0.18 <sup>c</sup>
Phenylalanine	93.17 ± 1.16 <sup>c</sup>	93.16 ± 1.22 <sup>c</sup>	93.66 ± 1.31 <sup>c</sup>	97.89 ± 1.61 <sup>d</sup>	90.99 ± 1.69 <sup>b</sup>	98.62 ± 0.77 <sup>d</sup>	90.56 ± 0.72 <sup>b</sup>	94.35 ± 0.97 <sup>c</sup>	113.20 ± 0.95 <sup>e</sup>	88.05 ± 0.48 <sup>a</sup>
Methionine	93.33 ± 0.95 <sup>c</sup>	92.48 ± 1.02 <sup>c</sup>	90.47 ± 1.23 <sup>c</sup>	98.19 ± 3.35 <sup>d</sup>	86.44 ± 2.72 <sup>b</sup>	97.25 ± 0.65 <sup>d</sup>	83.60 ± 1.14 <sup>ab</sup>	82.75 ± 1.66 <sup>a</sup>	104.25 ± 1.29 <sup>e</sup>	84.88 ± 0.53 <sup>ab</sup>
Cysteine	98.25 ± 1.65 <sup>c</sup>	99.20 ± 1.58 <sup>c</sup>	96.62 ± 1.92 <sup>c</sup>	102.99 ± 3.17 <sup>d</sup>	91.05 ± 3.02 <sup>b</sup>	103.45 ± 0.90 <sup>d</sup>	90.76 ± 1.03 <sup>b</sup>	88.67 ± 1.44 <sup>b</sup>	118.16 ± 1.13 <sup>e</sup>	85.27 ± 0.62 <sup>a</sup>
Threonine	95.88 ± 0.90 <sup>c</sup>	95.27 ± 0.90 <sup>c</sup>	95.08 ± 1.01 <sup>c</sup>	99.73 ± 1.54 <sup>d</sup>	90.83 ± 2.21 <sup>b</sup>	100.39 ± 0.66 <sup>d</sup>	85.64 ± 1.00 <sup>a</sup>	89.79 ± 0.93 <sup>b</sup>	101.04 ± 1.63 <sup>d</sup>	87.03 ± 0.44 <sup>a</sup>
Isoleucine	96.99 ± 0.91 <sup>d</sup>	97.14 ± 0.88 <sup>d</sup>	97.16 ± 0.97 <sup>d</sup>	100.73 ± 1.30 <sup>e</sup>	91.15 ± 2.02 <sup>ab</sup>	101.27 ± 0.59 <sup>e</sup>	89.45 ± 0.96 <sup>b</sup>	86.41 ± 1.16 <sup>a</sup>	104.98 ± 1.24 <sup>f</sup>	92.62 ± 0.37 <sup>c</sup>
Valine	94.20 ± 1.12 <sup>b</sup>	94.10 ± 1.13 <sup>b</sup>	94.14 ± 1.25 <sup>b</sup>	97.55 ± 1.77 <sup>c</sup>	87.10 ± 2.29 <sup>a</sup>	98.89 ± 0.77 <sup>c</sup>	88.07 ± 0.94 <sup>a</sup>	87.84 ± 1.07 <sup>a</sup>	104.43 ± 1.24 <sup>f</sup>	87.78 ± 0.47 <sup>a</sup>
Leucine	96.68 ± 0.70 <sup>c</sup>	95.88 ± 0.72 <sup>c</sup>	95.16 ± 0.84 <sup>c</sup>	99.04 ± 1.05 <sup>d</sup>	90.30 ± 1.54 <sup>a</sup>	98.77 ± 0.54 <sup>d</sup>	89.57 ± 0.74 <sup>a</sup>	90.18 ± 0.80 <sup>a</sup>	103.03 ± 0.91 <sup>e</sup>	92.41 ± 0.32 <sup>b</sup>
Histidine	96.16 ± 0.70 <sup>d</sup>	96.35 ± 0.64 <sup>d</sup>	96.19 ± 0.77 <sup>d</sup>	97.31 ± 1.14 <sup>d</sup>	90.30 ± 1.42 <sup>b</sup>	99.88 ± 0.62 <sup>e</sup>	89.49 ± 0.60 <sup>ab</sup>	93.61 ± 0.58 <sup>c</sup>	101.00 ± 0.87 <sup>e</sup>	88.34 ± 0.38 <sup>a</sup>
Arginine	97.24 ± 0.50 <sup>cd</sup>	97.84 ± 0.48 <sup>bc</sup>	96.79 ± 0.56 <sup>c</sup>	98.38 ± 0.77 <sup>e</sup>	97.03 ± 0.50 <sup>cd</sup>	100.17 ± 0.41 <sup>f</sup>	97.19 ± 0.21 <sup>cd</sup>	95.16 ± 0.48 <sup>b</sup>	109.01 ± 0.67 <sup>g</sup>	90.99 ± 0.30 <sup>a</sup>

In the same row, values with different small letter superscripts mean significant difference ( $P < 0.05$ ).

**Table 7:** Apparent digestibility coefficients (ADC, %) of amino acids (excluding tryptophan and including cysteine) in test feedstuffs consumed by *P. monodon*.

yeast, nucleic acid nitrogen is present mostly in the form of RNA and represents about 20% to 25% of the nitrogen [29].

### Proximate composition and digestibility

The protein quality of dietary ingredients is usually the leading factor affecting fish performance, bioavailability of proteins and amino acids in feedstuffs is an important factor to consider, in part because it is related to the quantity of nitrogen absorbed by shrimp. During high density cultivation, almost 78% of nitrogen from dietary protein is released to the environment [30]. Low digestibility of feeds leads to accumulation of nitrogen wastes in water and soil, which in turn can lead to shrimp disease and higher death rates [27], as well as pollution and eutrophication of water. Apparent dry matter digestibility provides a measure of the total quantity of an ingredient that is digested and absorbed. Because all components of a diet are not digested equally, ADMD can provide a better estimate of the quantity of indigestible material presented in a feed ingredient than digestibility coefficients for individual nutrients [15]. In the present study, the three fish meals were relatively similar in proximate composition, except Peruvian FAQ fish meal with lower lipid content (8.89%), fish meal protein was well digested by juvenile *P. monodon*, which was higher than those reported for juvenile *Litopenaeus vannamei* [20,31]. Nutrient composition, quality and digestibility of amino acids in fish meals varies with the freshness and type of the raw ingredients and processing during manufacture [32]. According to other previous published research, fish meals used as an ingredient in feeds for shrimp should have at least 85% digestibility protein, contain  $<150 \text{ g/kg}^{-1}$  ash, and dried at low temperatures to ensure good protein bioavailability and reduce nitrogen wastes that pollute the shrimp farms and outflow water [33]. These requirements were fulfilled by Peruvian steam fish meal and Peruvian FAQ fish meal. The differences in APD among the present fish meal could be attributed to several factors, such as different raw materials, location, or processing conditions used to produce the meal (steam or FAQ), as well as unknown factors. The differences in APD could also be a consequence of Maillard's reaction, which is known to reduce availability of amino acids caused by interaction between reducing sugars and amino acids [31]. However, this effect was not measured in this study. Further research is needed to confirm this hypothesis.

In the present study, the apparent digestibility for dry matter of some plant-based ingredients such as peanut meal (68.30%) and rapeseed meal (75.09%) were lower than that of soybean meal (86.80%), cottonseed meal (87.31%) and wheat flour (115.71%). This is anticipated

because peanut meal and rapeseed meal contain higher levels of ash than soybean meal. Increased use of plant-protein supplements in *P. monodon* diets will reduce feed cost and assist in reducing dependence on fish meal as the primary protein source in shrimp diet. In addition, soybean meal protein is considered to be highly digestible to many crustacean species [34]. Dry matter digestibility of feedstuffs consumed by *P. monodon* tended to decrease as the fibre and ash content of the feedstuffs increased. High-starch ingredients such as wheat flour tended to be better digested by *P. monodon* than those containing high quantities of fiber and ash. The low dry matter digestibility of some plant products appears to be related to the quantity and chemical composition of the carbohydrates they contain [35]. Rapeseed meal contains a high proportion of fiber besides other anti-nutritional factors such as tannins, sinapin and phytic acid [36]. Moreover, rapeseeds are also known to contain glycosylates, whose metabolites have a goitrogenic activity in all animals, including fish [37]. The low digestibility of rapeseed meal found in the present experiment was probably due to the high fibre and anti-nutritional factors [1].

Brewer's yeast is a source of nucleic acids and polysaccharides including glucans, it also contains proteins, vitamins, sixteen amino acids and fourteen or more minerals that are frequently used as feed ingredients in aquaculture [38]. In the present experiment, shrimp fed the brewer's yeast diet showed higher growth performance than in the reference diet. On the contrary, the ADMD, APD, AAAD and AED of brewer's yeast and brewer's yeast diet were lower than other feedstuffs and diets, indicating a lower digestible value of brewer's yeast than other feedstuffs. The digestible evaluation of brewer's yeast as feed ingredient in shrimp was scarce. The lower digestibility of shrimp fed brewer's yeast diet may be caused by intact yeast cells, as probably not all intracellular ingredients become available to the shrimp [39].

The proteins in tested diets were all highly digestible to *P. monodon* (Table 5). Crustaceans are proficient at digesting proteins as shown by the high protein to energy ratios in these species compared to those in fish [40]. The associative effects of nutrients in diets of crustaceans have been reported to affect feed digestibility especially the interactions of plant meals rich in carbohydrate and animal meals rich in protein [40]. It is clear in this study that for *P. monodon*, the relative amount of dietary protein had an effect on the ADMD (63.52% to 80.07%) but not on APD (83.33% to 88.70%). In *P. monodon*, increasing dietary carbohydrate could increase the crude fat in the feces [41]. However, no data has been available to understand the associative effects among feed ingredients in crustaceans.

## Amino acids composition and digestibility

The apparent amino acid digestibility coefficients varied from 89.35% for lysine in cottonseed meal to 102.38% for lysine in wheat flour. Physiologically, ADCs should range between 0% and 100%. However, digestibility values higher than 100% have been reported in other studies [15,19,42,43]. Digestibility of some amino acids, such as lysine and methionine, may be overestimated because they are highly soluble in seawater [19]. A value of 110% for protein digestibility of wheat gluten was reported for *P. setiferus* [15], which was attributed to interactions among nutrients. Another factor that may affect apparent digestibility is the high temperatures that are sometimes used during manufacturing processes of feed ingredients. This may damage amino acids structure and affect digestibility (Maillard reaction), and they are eliminated in the urine without proper assimilation in the cells [31]. Hence, altered amino acids caused by high temperature processing can overestimate apparent digestibility.

No significant differences were found in AAAD among Peruvian steam fish meal, Peruvian FAQ fish meal and local fish meal; moreover, soybean meal and peanut meal had the comparable amino acids digestibility with the present three fish meals. However, shrimp head meal and wheat flour had the higher AAAD than the present three fish meals, and cottonseed meal, rapeseed meal and brewer's yeast had the lower AAAD than the present three fish meals. This suggested that soybean meal, peanut meal, shrimp head meal and wheat flour could be used as preferable ingredients in shrimp diets. Digestibility of cysteine was high in wheat flour; this amino acid is more easily altered by the Maillard reaction between reducing sugar and amino acids that occurs during heat processing of feed ingredients [31].

The apparent bioavailability of amino acids for soybean meal in the present manuscript was higher than the published research [14]. Soybean meal as in our study was demonstrated to be a good source of highly available amino acids for *P. monodon*. In general, the profile of amino acids for shrimp head meal in our study was higher than that of levels in the previous published research [21]. Moreover, ADMD, APD, AAAD and AED were higher in shrimp head meal than in fish meal. The higher digestibility of shrimp head meal may result from lower ash content and may be a good source of protein and amino acids for juvenile *P. monodon*. The nutrients in peanut meal vary with season and method of preparation, which is probably sufficient to lead to changes in digestibility. The present amino acids digestibilities of cottonseed meal and rapeseed meal were comparable to other test feedstuffs though significant differences were found among them. Our results suggest that cottonseed meal and rapeseed meal could be the good source of protein and amino acids for *P. monodon* by removing the anti-nutritional factors in a proper way [1]. No previous reports appear to consider amino acids digestibilities of cottonseed meal and rapeseed meal by the shrimp.

## Conclusion

Great variability in the coefficients of apparent digestibility of dry matter, protein and amino acids of ten feedstuffs was found in the present study. These variables should be considered in substitution of total protein by amino acids for more accurate and economical formulation of shrimp feeds. The most digestible ingredients were, in descending order, shrimp head meal, Peruvian FAQ fish meal, Peruvian steam fish meal, local fish meal for the marine feedstuffs; soybean meal and wheat flour are more preferable for *P. monodon* feed compared to other plant feedstuffs such as peanut meal, cottonseed meal and rapeseed meal; brewer's yeast induced a positive feeding and growth

response in *P. monodon* though its digestibility is poor, it might also be of interest to study the effect of processing technology on nutrients digestibility of brewer's yeast.

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## Conflict of Interest

There are no conflicts of interest.

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