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NUTRICIONAL ASSESSMENT OF INGREDIENTS USED IN PACIFIC WHITE SHRIMP FEED[1]

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ABSTRACT – Studies on feeding and nutrition of shrimp are still quite scarce; little is known about the use of agribusiness byproducts in shrimp diets. Therefore, this study aimed to perform nutritional and energy assessments of protein-based ingredients for feed of shrimp of the *Litopenaeus vannamei* species. The design was completely randomized, with six treatments and four replications: a standard diet and five test diets composed of 70% standard diet and 30% test ingredients (poultry viscera flour - PVF, cassava leaf hay - CLH, shrimp head flour - SHF, sugarcane yeast - SCY and castor bean meal - CBM). We used a total of 720 shrimps with mean weight of 8 g each. The parameters of quality showed no significant change by the Tukey's test ($p > 0.05$). The apparent digestibility coefficients of PVF, CLH, SHF, SCY and CBM were respectively 27.44, 76.26, 77.78 and 90.10% for dry matter; 76.61, 70.44, 97.67 and 78.29% for protein; and 33.10, 51.19, 90.70 and 78.05% for gross energy. The digestible energy of the ingredients was 1749, 2457, 3914, 3030 and 2130 kcal/ kg; and digestible protein was 42.4, 16.09, 54.62, 23.71 and 14.31%. The SHF reached the highest coefficients of apparent digestibility, crude protein, gross energy and digestible energy. The SCY had the largest apparent digestibility of dry matter. Both SHF and SCY presented improved availability of nutrients and energy for *L. vannamei.*

Keywords: Alternative food. Digestible energy. *Litopenaeus vannamei.*

AVALIAÇÃO NUTRICIONAL DE INGREDIENTES PARA O CAMARÃO BRANCO DO PACÍFICO

RESUMO – Os estudos sobre alimentação e nutrição de camarões ainda são muito escassos, pouco se sabe sobre o aproveitamento pelos camarões de subprodutos da agroindústria, portanto o objetivo deste trabalho foi à avaliação nutricional e energética de ingredientes proteicos para camarões (*Litopenaeus vannamei)*. O delineamento foi inteiramente casualizado, com seis tratamentos e quatro repetições: uma Reference diete cinco dietas teste compostas de 70% da Reference diete 30% do ingrediente teste (farinha vísceras de aves-FVA, feno folha de mandioca- FFM, farinha cabeça de camarão-FCC, levedura de cana-de-açúcar-LC e farelo de mamona -FM). Utilizou-se 720 camarões com peso médio de 8g. Os parâmetros de qualidade não apresentaram diferença significativa pelo teste de Tukey ($P > 0,05$). Os coeficientes de digestibilidade aparente dos ingredientes FVA, FFM, FCC, LC e FM foram respectivamente, 27,44; 76,26; 77,78 e 90,10% para matéria seca;76,61; 70,44; 97,67 e 78,29% para proteína e (33,10; 51,19; 90,70 e 78,05%) para energia bruta. A energia digestível dos ingredientes foi 1.749, 2.457, 3.914, 3.030 e 2.130 kcal/kg e proteína digestível foi de 42,4; 16,09; 54,62, 23,71 e 14,31%. A FCC apresentou os maiores coeficientes de digestibilidade aparente da proteina bruta e energia bruta e para energia digestível. A LC apresentou o maior valor do coeficiente de digestibilidade aparente da matéria seca. A FCC e a LC são os ingredientes que apresentaram os melhores aproveitamentos dos nutrientes e da energia para *L. vannamei.*

Palavras-chave: Alimentos alternativos. Energia Digestível. *Litopenaeus vannamei.*

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INTRODUCTION

The main species of marine shrimp commercially produced worldwide is the *Litopenaeus vannamei* (DASTIDAR; MALLIK; MANDAL, 2013). This species is typically euryhaline and has the ability to withstand wide ranges of salinity (0.5 - 40 g/ L), which prompted its cultivation in olygohaline waters (HAVIRD; SANTOS; HENRY, 2014).

Shrimp marine species farming may be feasible in inland waters of low salinity which are unsuitable for conventional agriculture, becoming an alternative to reduce costs and enable shrimp farming in areas of low agricultural production (PRAPAIWONG; BOYD, 2014).

Alternative ingredients can replace conventional protein foods used in feed of aquatic organisms, which occurs largely due to the high cost of these ingredients, since feeding expends about 60 to 70% of the production costs (CUMMINS et al., 2013).

A higher coefficient of digestibility of certain ingredients might have economic effect by increasing the feeding efficiency, influencing the performance and quality of water through waste reduction in farming environments (GHUO et al., 2006). The low digestibility of food leads to accumulation of residues in soil and water, making the environment hypereutrophic and of low quality, causing diseases to animals (LIN et al., 2006).

By knowing the digestibility of alternative ingredients, we can reduce costs in feed formulation; however, maintaining a formula that still fulfill the nutritional requirements of animals (BUGLIONE‑NETO et al., 2013).

Protein-based food represents the highest percentage of costs in feed formulation for aquatic animals because of the large amount required and due to their higher costs in diets (LEMOS; LAWRENCE; SICCARDI III, 2009).

The ingredients currently used as protein source in aquaculture can be replaced, in part or full, by other alternatives, such as soy meal. However, it is extremely important to perform studies on the digestibility level of such ingredients to optimize shrimp nutrient uptake.

Alternative ingredients originating from the agricultural industry can be critical for the maintenance and growth of production and consequent food cost reduction for aquatic animals.

Poultry viscera flour is a byproduct of slaughtering industry and can be used in monogastric animal feed manufacturing. This residue appears as a protein alternative food for aquatic organisms, since it is widely available and has high nutritional value. The crude protein content ranges from 55 to 65% with apparent digestibility coefficient between 78.7% and 90.4%, found in experiments with *L. vannamei* (CRUZ-SUÁREZ et al., 2007).

Cassava (Manihot esculenta Crantz) is a widespread crop worldwide, and is one of the main sources of energy for human nutrition in tropical countries (DA; LUNDH; LINDBERG, 2012). Its leaves are considered a byproduct from root harvesting and, in most cases, wasted in all regions. According to a study of Ramos et al. (2012), cassava shoot dry matter makes 92.7% of the total biomass, with a total crude protein of 21.9% and gross energy of 19.5 MJ/ kg. Even though little used to feed aquatic organisms, whole hay of cassava leaves could be an important ingredient to reduce feeding costs.

Shrimp production and processing generate solid waste, consisting of large amounts of shrimp head and shell, which correspond to approximately 40% of total produced weight, being then discarded at the end of the processing (ASSIS; STAMFORD; STAMFORD, 2008). Shrimp meal can be a good form of exploitation of this remaining material, bringing economic and environmental benefits. Its nutritional composition is rich and has a crude protein rate of 60.6% (LIMA et al., 2007), besides of essential amino acids (BHASKAR et al., 2010), which is quite close to fishmeal.

Another important ingredient, mainly in northeastern Brazil, is the sugarcane yeast (*Saccharomyces cerevisiae*). It is a byproduct from ethanol industry, in which Brazil is emerging as the world's largest producer. Moreover, it consists of a feasible alternative for aquatic animal diets, since it has good nutritional characteristics, such as crude protein levels ranging from 22.41 to 40.18% with good balance of essential amino acids, particularly lysine (POVEDA-PARRA et al., 2013). According Hisano et al. (2008), whole yeast has a high protein content and good digestibility of nutrients and amino acids.

Eventually, castor bean (*Ricinus communis* L.), which is well adapted to high temperatures, easy handling and low production cost. Furthermore, according to Mota and Pestana (2011), there is a great potential for the use of agro-industrial waste of castor bean in animal feeding, since its detoxified bran shows a percentage of dry matter of 95.25%, crude protein of 39.82%, crude fiber of 28.48%, ether extract of 1.58%, mineral material of 6.31%, and nitrogen free extract of 23.81%. This ingredient quality and the social background, where such raw material production is inserted, are important requirements for the choice of ingredients that will be used in shrimp feed manufacturing.

Therefore, the aim of this study was to determine the nutritional and energy value of the protein-based ingredients: poultry viscera flour, cassava leaf hay, shrimp head flour, sugarcane yeast and castor bean meal for Pacific white shrimp.

MATERIAL AND METHODS

Evaluations were carried out at an experimental area of the Research Center for Fisheries Resources and Aquaculture (NEPA) of the *Universidade Federal do Recôncavo da Bahia* - UFRB (Federal University of Bahia Recôncavo - UFRB), from December of 2011 to March of 2012. We used a total of 720 shrimps of the *L. vannamei* species with an average weight of 8 g, which were provided by the Oruabo Experimental Farm - Bahia Pesca SA, located in Santo Amaro, Bahia, Brazil.

The experiment was accomplished in a completely randomized design with a standard diet and five treatments with four replications. Preliminarily, shrimps were acclimatized for 21 days at salinity of 0.8 g / L in fiberglass tanks with 1,500 liters.

Water quality variables were measured at a daily basis (pH, dissolved oxygen, temperature, salinity and conductivity), using a multiparameter probe (HANNA HI 9828). Weekly, total alkalinity was measured by titration method described by Golterman, Clymo and Ohnstad (1978), at the Water Quality laboratory of the UFRB. Yet the degree of water hardness was made with the Dureza Total GH kit; and the ammonia content was measured using Amônia Tóxica kit of the LabconTest®.

Daily, 80% of the water from 1,500-L polyethylene tanks was renewed by public network supply together with seawater, until reach a salinity level of 0.8 g/ L. After mixing fresh and seawater, we added dolomitic lime at a ratio of 1.0 kg/ m^2, applying firstly 50% and the remainder divided into doses weekly applied during the cultivation. This water remained in these tanks at constant aeration for 24 h, in order to volatilize chlorine and to dilute the dolomitic limestone.

The following ingredients were assessed: poultry viscera flour (PVF), cassava leaf hay (CLH), shrimp head flour (SHF), sugarcane yeast (SCY) and castor bean meal (CBM). These ingredients underwent chemical analysis referring to dry matter (DM), mineral matter (MM), crude protein (CP) and ether extract (EE), following method described by the AOAC (2005).

Treatments consisted of a reference diet and five test diets composed of 70% of the reference diet and adding 30% of the ingredient to be tested. As shown in Table 1, the reference diet was prepared according to the method of NRC (2011) for crude protein and digestible energy, and as proposed by Tacon, Metian and Hasan (2009) for amino acids, vitamins and minerals. The chemical indicator, chromium oxide (Cr_2O_3), was added to the feed at a concentration of 1%, as described by Rostagno and Sakomura (2007). The ingredients were homogenized, wetted with water at 70 °C, pelleted by meat grinder and placed on trays for drying in an oven at 55±5 °C until constant weight.

Table 1. Percent composition of the reference diet used in digestibility trial for shrimps of the *L. vannamei* species.

Ingredients	Reference diet (%)
Fishmeal	35.0
Soybean meal	28.5
Wheat flour	32.2
Soya oil	2.20
Premix (min + vit)[1]	1.55
Common salt	0.50
BHT[2]	0.05
Total	100
Analyzed and calculated values	
Crude protein (%)	34.63*
Shrimp digestible energy (kcal/kg)	4534
Ether extract (%)	4.50*
Crude fiber (%)	1.66
Calcium (%)	1.69
Total phosphorus (%)	1.02
Total arginine (%)	2.28
Total lysine (%)	2.08
Total Met + Cystine (%)	1.29
Total threonine (%)	1.41

[1]Folic acid (min) 500 mg/ kg. Pantothenic acid (min) 6,500 mg/ kg. B.H.T (min) 5,000 mg/ kg. Biotin (min) 21 mg/ kg. Copper (min) 1,000 mg/ kg. Choline (min) 140 g/ kg. Iron (min) 1,000 mg/ kg. Iodine (min) 50 mg/ kg. Manganese (min) 5,000 mg/ kg. Niacin (min) 10 g/ kg. Selenium (min) 20 mg/ kg. Zinc (min) 10 g/ kg. Vitamin A (min) 500,000 IU/ kg. Vitamin B_1 (min) 2,600 mg/ kg. Vitamin B_{12} (min) 10,000 mcg. Vitamin B_2 (min) 2,600 mg/ kg. Vitamin B_6 (min) mg/ kg. Vitamin C (min) 40 g/ kg. Vitamin D_3 (min) 160,000 IU/ kg. Vitamin E (min) 16,000 IU/ kg. Vitamin K_3 (min) 1,000 mg/ kg. [2] BHT = Butylated hydroxy toluene.* Assessed values.

Before the experiment start, the shrimps, with mean weight of 8g, were kept in 200-L hatchery tanks for seven days for acclimatization, at a stocking density of 30 animals / tank. Feeding was conducted up to apparent satiation, being carried three times a day at 08 am, 2 pm and 6 pm, throughout fifteen days.

Droppings were removed via container attached to the bottom tank, three times a day, and prior to feeding. The excreta were cleaned and oven dried at 55 °C for 24 hours, then placed in freezer (-100 ºC) until chemical analyzes were done. The material was removed from the freezer and subjected to dehydration by lyophilization, to obtain constant weight. The dried feces were ground and then submitted to chemical analyzes by the method of AOAC (2005).

Apparent digestibility coefficients (ADC) of the diets were estimated as follows (Nose, 1966):

ADC (%) = 100 - [100 x (%Cr_2O_3d / %Cr_2O_3f). (%Nf/ % Nd)]

In which:

ADC = Apparent Digestibility Coefficient (%);

%Cr_2O_3d = Chromic oxide rate in the diet;

%Cr_2O_3f = Chromic oxide rate in the feces;

%Nf = Percentage of energy, protein, dry matter or ether extract in the feces;

%Nd = Percentage of energy, protein, dry matter or ether extract in the diet.

Apparent digestibility of nutrients (ADn) was calculated using the formula described by Reightet, Braden and Craig (1990):

ADN (%) = (100/30) x [ADC test – (70/100 x ADC reference)]

In which:

ADC test = Apparent Digestibility coefficient of the test diet nutrients;

ADC reference = Apparent Digestibility coefficient of the reference diet nutrients.

Concentrations of chromium oxide in excreta and feedstuffs were analyzed at the Laboratory of Food Physical and Chemical Analyses of the Universidade Federal de Viçosa - UFV, using the acid digestion method proposed by Furukawa and Tsukahara (1966).

Gross energy, crude protein, dry matter, ether extract as well as digestible protein and energy were analyzed by the GLM procedure (General Linear Models). Additivity was tested by covariance analysis of the squared predicted values. Data normality was checked by an univariate procedure through W statistics (Shapiro-Wilk). In addition, variance homogeneity was evaluated by the Bartlett's test and differences were detected by the Tukey's test at 5% probability, using the SAS statistical software version 9.1 (SAS, 1999).

RESULTS AND DISCUSSION

There was no significant difference (p> 0.05) among treatments regarding the values found for water quality. According to Lourenço et al. (2009), these values are adequate for shrimp of the *L. vannamei* species.

Table 2 displays the percent composition of the assessed nutrients (DM, CP, EE and MM) and gross energy of the feedstuffs.

Table 2. Chemical composition (in natural matter) of the testing ingredients.

Ingredient	DM (g/kg)	CP (g/kg)	MM (g/kg)	EE (g/kg)	GE (kcal/kg)
PVF	95.79	55.35	10.43	19.08	5,283
CLH	93.66	22.81	6.17	5.76	4,800
SHF	91.27	55.92	14.03	7.24	4,316
SCY	89.18	30.29	13.76	0.69	3,883
CBM	92.11	30.13	6.19	7.56	4,880

PVF= poultry viscera flour; CLH = cassava leaf hay; SHF = shrimp head flour; SCY = sugarcane yeast; CBM = castor bean meal; DM = dry matter; CP = crude protein; MM = mineral matter; EE = ether extract; GE = gross energy.

There was significant difference between all apparent digestibility coefficients, digestible energy and digestible protein of the tested ingredients at 5% probability by the Tukey's test. Table 3 displays the ADCs of the ingredients for DM, GE, CP, digestible energy and protein.

PVF had the lowest CDADM (27.44%) among the tested ingredients, which is well below the findings of Cruz-Suárez et al. (2007) (90.8%). However, our result corroborates that of Carvalho (2011), which showed a near value (26.5%). These differences may be the result of different methods of PVF processing of each experiment.

According to Yang et al. (2009), the dry matter digestibility of food ingredients consumed by *L. vannamei* tend to decrease as the fiber content and ashes increase. The same authors report that low dry matter digestibility of a few plant products seems to be associated with carbohydrate quantity and chemical composition.

Carvalho (2011) and Cruz-Suárez et al. (2007) observed CDAGE values of PVF (46.4 and 93.3%, respectively) higher than the ones found in this study (33.10%). This difference might have been due to the lipid content (19.08%), as seen in Table 2. This component was higher for the PVF than for the

Table 3. Apparent Digestibility coefficient (ADC) of the protein-based feedstuff for the *L. vannamei* shrimp.

Variables	Ingredient						
	PVF	CLH	SHF	SCY	CBM	CV(%)	DP
CDADM (%)	27.44^{D}	76.26^{B}	77.78^{B}	90.10^{A}	69.68^{C}	3.84	22.1
CDAGE (%)	33.10^{E}	51.19^{C}	90.70^{A}	78.05^{B}	43.65^{D}	2.43	22.2
CDACP (%)	76.61^{B}	70.44^{C}	97.67^{A}	78.29^{B}	47.49^{D}	2.95	16.7
DE(kcal/kgDM)	1749^{E}	2457^{C}	3914^{A}	3030^{B}	2130^{D}	2.72	778.8
DP (%DM)	42.4^{B}	16.09^{D}	54.62^{A}	23.71^{C}	14.31^{D}	2.94	16.7

CDADM = Apparent Digestibility coefficient of dry matter; CDAGE = Apparent Digestibility coefficient of gross energy; CDACP = Apparent Digestibility coefficient of crude protein; DE = digestible energy; DP = digestible protein; PVF= poultry viscera flour; CLH = cassava leaf hay; SHF = shrimp head flour; SCY = sugarcane yeast; CBM = castor bean meal; Values followed by different letters in the same line show significant differences ($p < 0.05$).

other assessed ingredients, and superior to the levels found by the above-cited authors (13.15% and 12.6%).

As shrimps have a restrict capacity to digest diets high in lipids, the surplus of such element may have affected the metabolic functions of the crustacean, reducing their growth and survival (HU et al. 2008). In this sense, most complex carbohydrates and proteins are better used by shrimps as main sources of energy (OLMOS et al., 2011).

The PVF also presented a major CDACP (76.61%), which was higher than that reported by Carvalho (2011) (27.7%), but lower than those found by Siccard et al. (2006) and Cruz-Suárez et al. (2007) (78.7% and 90.4%, respectively). Our outcomes for CDACP may have followed exploitation level of the protein, which showed a DP rate of 42.4%, directly influencing the coefficient above mentioned.

Several factors may affect DP such as enzyme inhibitors, improper diet and feed formulations with chemically and physically available proteins. Protein availability varies with ingredient's chemical composition, used raw material, cooking method, drying and storage, as well as the time spent in storing like drying at high temperature can reduce DP and produce anti-nutritional factors in some feed ingredients (YANG et al., 2009).

CLH showed the second highest ADC for DM (76.26%) and the thirds for GE (51.19%) and CP (70.44%). Moreover, this ingredient presented the third highest value for DE (2,457 kcal/kg) and the fourth for DP (16.09%).

By studying the digestibility of cassava byproducts in Nile tilapia, Santos et al. (2009) found inferior values for digestibility coefficient of shoot DM (65.53%) and CP (53.00%), however superior ones for GE (55.28%). According to Ramos et al. (2012), the crude fiber content in CLH (24.5%) may have contributed to the reduction in the use of this material, since the fiber interferes with the proper use of the energy of nutrients.

Cassava shoot has also antinutritional factors such as linamarin, which is a protease and polyphenol inhibitor, forming most stable compounds and interfering with the content of extractable and digestible proteins. Protease inhibitors are related to the defense mechanism of plants and are capable of inhibiting enzymes such as trypsin, chymotrypsin and carboxypeptidase, reducing the use of nutrients by the animal, and thus declining their development (TRAN et al., 2011).

Nutritional and antinutritional factors of plants may be influenced by harvest time, weather, plant maturity and soil fertility. By eliminating antinutritional factors, ingredients may have their quality enhanced; thus, certain elements as temperature and time become essential to the final product quality. Nevertheless, shrimp diets should be based on food with proteins of high biological value upon dehydration that removes toxic agents.

SHF presented a CDADM of 77.78%, which is lower than that found by Terrazas-Fierro et al. (2010) (84.0%), but higher than that found by Akiyama et al. (1989) (56.8%). Such differences have relationship with ingredient quality and processing methods, which have varying times and temperatures of preparation. It can also be related to the species used and excess of other parts such as shrimp shell in the feedstock. In contrast, CDACP (97.67%) corroborates the results of Terrazas-Fierro et al. (2010) (98.0%), and higher than those found by Akiyama et al. (1989) (74.6%) and Mu et al. (2000) (88.2%), which may have been influenced by the ability of crustaceans to better use the protein of the soluble carbohydrates (ROSAS et al., 2002).

Shrimps are omnivores and scavengers, i.e. consume shells of other dead shrimp; thereby ingest sources of chitin, which in turn has nitrogen in its composition. SHF is rich in chitin, a carbohydrate that serves as an energy source for shrimp and is fundamental to better protein exploitation and thus contribute to the growth of these animals (LEI; HSIEH; CHEN, 1989).

SCY had an ADC for DM of 90.10%, GE of 78.05% and CP of 78.29%, being the highest for DM, and the second highest for GE and CP. This product also presented the second highest value of DE (3,030 kcal/kg), behind only of SHF (3,914 kcal/ kg) and with the third major value for DP (23.71%).

Hisano et al. (2008) made a digestibility research using autolyzed sugarcane yeast in Nile tilapias; the results showed lower values of DM

(85.9%) and CP (72.2%) and higher ones of GE (78.05%) when compared to the results of our study.

Whole SKY has intact cell wall, rich in heteropolysaccharides structured in complex carbohydrates and proteins, such as mannoproteins and glucan, which may compromise the use efficiency, as well as other nutrients (HISANO et al., 2007).

Studies carried out by Hisano et al. (2008), testing the cell wall of sugarcane yeast in Nile tilapias showed that the complex structure of carbohydrates and protein, on the one hand, compromises protein use, however, on the other hand, improves the ADC of DM and GE.

Therefore, processes that aim at best use of SKY are needed, e.g. autolysis that improves the feed use efficiency. This ingredient also provides a good source of essential amino acids, but has some factors that affect its use in animal feed; such factors are non-protein nitrogen content and the cell wall, leading to an overestimation of the protein content within it.

ADCs found for CBM were 69.68%, 43.65%, 47.49% and 63.97% of DM, GE, CP and EE. These represented the third highest for DM and the fourth largest value for GE and CP. The material also showed an DE (2,130 kcal / kg) higher than the PVF one (1,749 kcal / kg), but the use of protein was the lowest among all materials (23.71%).

The results for CBM can be explained because of the presence of ricin, ricinine and albumins, which are allergenic factors that cause red cell agglutination, arousing cell death by inhibiting protein synthesis (BUENO et al., 2014). This way, food processing is required for inactivation of these factors and production of a most suitable meal for animal consumption.

Unfortunately, processes to reduce antinutritional factors can reduce the protein levels, increasing deficiencies on essential amino acids as lysine, tryptophan and histidine. This problem would be a result of leaching and possible vaporization of nitrogen substances during the processing (AKANDE; ODUNSI, 2012). Moreover, the castor bean energy may decrease depending on the exposure time under treatment. This may be because part of the soluble portion of nutrients is lost to the fluid during immersion in water and fermentation caustic soda (ANNONGU; JOSÉ, 2008). In addition, there are several detoxification methods of castor bean byproducts which associated to their nutritional value make these ingredients potentially good for shrimp food.

DE values of the ingredients are related to the ADCs (DM, GE, CP and EE). SHF had the best result of DE (3,914 kcal/ kg/ DM) due to factors such as increased exploitation by shrimps when using protein-derived energy and as function of apparent digestibility of DM (77.78%), GE (90.70%) and EE (93.97%).

Similarly, though in reverse, PVF showed an DE with the lowest value (1,749 kcal / kg / DM) and CDAGE (33.10) also lower, even though the higher gross energy (5,283 kcal / kg), second best CDACP (76 , 61%) and CADEE (73.21%) among all ingredients. These results indicate that shrimps could not exploit the nutrients and hence had a lower energy use of PVF.

DE data of the ingredients may have been influenced by high contents of fat in diets and respective lipid profiles. In this case, saturated and monounsaturated fatty acids can be bioconverted from enzymatic action, producing some nutritional value that is inherent in their source. According to studies of Oujifard et al. (2012), the best nutritional results were obtained with lipids from marine animals and the requirement of polyunsaturated fatty acids should achieve a certain appropriate ratio with the fatty acids in the diet.

CONCLUSION

Shrimp head flour and sugarcane yeast were the ingredients that showed the best apparent digestibility coefficients among all nutrients tested and also the digestible energy for shrimp of the *L. vannamei* species. New researches should be performed in order to improve the nutritional analysis of the five tested ingredients.

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