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Evaluation of commercial Pacific white shrimp *Litopenaeus vannamei* (Boone, 1931) feeds: growth performance and body carcass analysis

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ABSTRACT

Growth performance, survival rate, productivity, and carcass analysis were examined in the whole grow-out production system for Pacific white shrimp *Litopenaeus vannamei* fed four commercial diets over 15 weeks. Shrimp were held in twelve hapas nets with a size of 2 x 2 x 1 m and installed within the commercial ponds. The shrimp were stocked with the density of 100 shrimp m^{-2} per net in a completely randomized design (CRD). All feed used in this study was characterized with high protein levels within the range of 40 – 42% labeled as HP A and B; and medium protein levels (30 – 35%), labeled as MP A and B. Based on the proximate and nutritional profile analysis of the diet, the nutritional profile of HP B, MP A and MP B written on the feed bags showed an inconsistent results compared to the results of the test. Shrimp fed the highest protein level had higher final body weight; feed conversion ratio, thermal growth coefficient, survival rate and average daily growth compared to MP B. Shrimp fed higher protein level also exhibited the lowest feed conversion ratio compared to the group of shrimp fed with medium protein. The results obtained in this study indicated that with small difference in growth rates, especially between HP groups compared with MP A, there is still a chance to re-formulate the diet to produce a cost-effective diet that still fulfill the specific nutrient requirement of the shrimp. Feed did not influence the nutritional deposition of the whole body of shrimp, but it seemed due to the inappropriate drying techniques

Keywords: Protein level, growth, carcass, *Litopenaeus vannamei*, specific nutrient

ABSTRAK

Analisis laju pertumbuhan, tingkat kelulushidupan, dan karkas telah dilakukan di dalam sistem produksi pembesaran untuk udang putih *Litopenaeus vannamei* yang diberi pakan komersial selama lebih dari 15 minggu. Udang dipelihara di dalam 12 jaring hapa dengan ukuran 2 x 2 x 1 m^3 dan dilakukan di dalam kolam komersial. Udang dipelihara dengan padat tebar 100 udang m^{-2} per jaring dalam rancangan acak lengkap. Seluruh pakan yang digunakan dalam uji coba ini dikarakterisasikan dengan pakan protein tinggi dengan kisaran 40 – 42% dan diberi label HP A dan HP B; dan pakan dengan level protein menengah (30-35%) diberi label MP A dan MP B. Berdasarkan hasil uji proksimat dan profil nutrisi pakan, profil nutrisi pakan HP B, MP A dan MP B yang tertulis di label karung pakan menunjukkan hasil yang tidak konsisten dibandingkan dengan hasil uji. Udang yang diberi pakan dengan level protein tinggi memiliki berat badan akhir, rasio konversi pakan, koefisien pertumbuhan berdasarkan suhu, tingkat kelulushidupan dan rerata pertumbuhan harian yang lebih baik dibandingkan dengan MP B. Udang yang diberi pakan dengan level protein tinggi juga menunjukkan tingkat rasio konversi pakan yang lebih rendah dibandingkan dengan udang yang diberi pakan dengan level protein menengah. Hasil pengamatan menunjukkan bahwa dengan perbedaan laju pertumbuhan yang kecil antara udang yang diberi pakan protein tinggi HP dibandingkan dengan MP A, masih ada peluang untuk melakukan formulasi pakan kembali untuk memproduksi pakan yang efektif secara biaya dan masih mampu memenuhi kebutuhan spesifik udang. Pakan tidak mempengaruhi deposisi nutrisi di tubuh udang, namun ini mungkin dikarenakan oleh teknik pengeringan yang tidak sesuai.

Kata kunci: Level protein, pertumbuhan, karkas, *Litopenaeus vannamei*, nutrisi spesifik

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1. Introduction

Aquaculture is one of the fastest-growing food production sectors in agriculture and plays a significant role in improving the national food security, income and nutritional status of people in many regions (Kannadhason and Muthukumarappan, 2010). As intensive aquaculture continues to expand, research on diet quality and feeding strategies is being continually refined (Hertrampf and Piedad-Pascual, 2012). In the evaluation of diet quality, ideally, other than specific nutritional requirements needed to sustain live processes and allow activity, growth and reproduction, aquafeed producer also need to understand the digestive process of the cultured aquatic organisms (NRC, 2011). As an omnivores species, shrimp actually have broad biochemical capacities to use diverse energetic sources as elements in their diet (Rosas and Carrillo, 2006). However, as reported by Tzuc et al. (2014), shrimp prefers protein over carbohydrates as an energetic source and the breakdown process take place in the hepatopancreatic chamber to produce small peptides and amino acids for building the structure and metabolism.

In commercial aquaculture feed, important nutrient properties that constitute feed quality include protein, carbohydrate, lipids, vitamins and minerals (Ayisi et al., 2017; Novriadi et al., 2021a; Novriadi and Davis, 2018; Novriadi et al., 2019). However, dietary protein has been considered as the most expensive nutrient in formulated feeds and an effort to reduce the inclusion level of protein could result in a drastic reduction in the growth of shrimp (Jackson et al., 2003). Therefore, proper formulation processes to meet the specific nutrient requirements of shrimp are needed. One of the best approaches to develop a sustainable and economically sound practical diet in the coming years is by using an “ideal” protein concept where formulation with proper level protein results in optimal efficiency of protein utilization and minimal nitrogenous waste (NRC, 2011). Thus, evaluating the quality of commercial diets with several protein levels using feed charts based on the commercial culture conditions may provide significant information to the farmers for optimizing their production cost-efficiency, growth of shrimp and productivity.

Pacific white shrimp *Litopenaeus vannamei* is the most widely cultured in Indonesia with an annual growth rate of around 8% through 2022, surpassing global growth rates of 5,6% (Rubel et al., 2019). The shrimp production system in Indonesia can be cultured intensively with a density of more than 200 post-larvae mL^{-2} per cycle (Novriadi et al., 2021a; Novriadi et al., 2020) to produce around 450,000 to 500,000 tons of shrimp every year and become the second-largest shrimp exporter to US, just behind India (Rubel et al., 2019). Currently, feed used in Indonesia contained around 35% crude protein and it was applied three to five times daily (Boyd et al., 2021). However, until recently, there is no reliable information about the effects of feeding the shrimp cultured in Indonesia with different levels of protein on the growth performance and carcass composition of the whole body of shrimp. Therefore, the objective of the present study was to evaluate the growth performance, including final body weight, thermal growth coefficient, feed conversion ratio, average daily growth and biomass, together with amino acid profile and carcass analysis of the whole-body of shrimp fed with four commercially available shrimp feed in Indonesia over full growing cycle until shrimp reach the consumption size.

2. Materials and Methods

2.1 Profile of commercial feeds

Four commercial feeds were used in this growth trial and divided into 2 type of feed, namely high protein feed (HP) and medium protein (MP). HP feed is composed of 42% crude protein (CP) and 6% crude lipid (CL); and 40% CP and 6% CL designed as HP A and HP B, respectively. MP feed composed with CP range from 32 – 35% and CL 6%; and CP 30% and CL 5%, designed as MP A and B, respectively. The products were stored at room temperature and dry place until further use. Detailed information about the proximate analysis of the commercial feeds from starter to finisher used in this study was presented in **Table 1.** The proximate composition and amino acid profile of the test diet on the grower stage were analyzed at the PT. Saraswanti Indo Genetech (Bogor, West Java, Indonesia) and presented in **Table 2**.

2.2 Experimental systems

The study was performed at the Jakarta Technical University of Fisheries (Jakarta, Indonesia). Post-larvae of Pacific white shrimp *Litopenaeus vannamei* (~ 0.003 - 0.005 g) were obtained from a commercial hatchery (CV. Salira Teknik Benur, Banten, Indonesia) and tested negative from White spot syndrome virus (WSSV), Taura syndrome virus (TSV), Acute hepatopancreatic necrosis disease (AHPND), Yellowhead disease (YHD) and bacterial infection (Fish Quarantine and Inspection

Agency, Lampung, Indonesia). Four treatments were carried out with post-larvae (PL) of *L. vannamei* in twelve hapa nets (2 x 2 x 1 m; *n* = 3) installed within the commercial ponds with a stocking density of 100 PL m^2 per net in a completely randomized design (CRD). The production period was 106 days and the treatments were labeled with (1) HP A, (2) HP B, (3) MP A and (4) MP B. All commercial diets used in this trial cover the starter, grower and finisher stage. HP A refers to the commercial diet with CP 42% and CL 6%. HP B refers to the diet with CP 40% and CL 6%. MP A refers to the commercial diet with CP ranging from 32 – 35% and CL 6% and MP B refers to diet with CP 30% and CL 5%. The primary source of mechanical aeration was with an air disc fine bubble diffuser, with one 0.5 HP paddlewheel (Minipadd™) per tank providing an additional aeration system. Zero water exchange was applied throughout the 106 days trial.

2.3 Feed management

Shrimp in all treatments were fed with the same feeding rate and feeding management system throughout the growth trial. The amount of feed used in this experiment was calculated based on the expected weight gain of 1 g $week^{-1}$, an FCR of 1.4, and a weekly mortality of 3 % during the grow-out period. During the trial, shrimp were fed four times per day and the daily ration was adjusted based on the percentage of body weight obtained after sampling the shrimp on a bi-weekly basis.

2.4 Growth sampling and water quality analysis

Shrimp were sampled weekly throughout the production cycle using a hand net (0.5 m in diameter and 1cm mesh size) to collect approximately 10 - 20 individuals per tank. Water quality (DO, pH, temperature, salinity, total dissolved solids, conductivity and oxidative redox potential) was monitored four times/day (06.00 – 07.00 h; 14.00 – 15.00 h; 17.00 – 18.00 h and 23.00 – 24.00 h) using hand refractometer (ATAGO, Japan) for salinity, and electrometry for dissolved oxygen and temperature (Lutron, DO 5510), and pH (ATC pH meter). At the end of the growth trial, shrimp were harvested fully, counted and batched weighed to calculate the final biomass, final weight, average daily growth (ADG), feed conversion ratio (FCR), thermal growth coefficient (TGC) and survival rate (SR) as follow:

$$ADG = \frac{(average\ final\ body\ weight\ gain)}{(days\ of\ culture)} \times 100$$

$$FCR = \frac{feed\ given\ (g)}{alive\ weigh\ gain\ (g)}$$

$$SR = \frac{final\ number\ of\ shrimp}{initial\ number\ of\ shrimp} \times 100$$

$$TGC = \frac{FBW^{1/3} - IBW^{1/3}}{\sum TD} \times 100$$

Where FBW is final body weight, IBW is initial body weight, T is water temperature (^{0}C) and D is number of trial days

2.5 Body carcass analysis

Upon termination of the trial, four shrimp from each tank, or twelve shrimp per treatment, were randomly sampled and stored at – 60 ^{0}C for body carcass analysis. Prior to the protein analysis, dried whole shrimp were rigorously blended and chopped in a mixer according to the standard methods established by The Association of Official Analytical Chemists (AOAC, 1990). Protein content, total fat and carbohydrate were analyzed using the Weibull method, crude fiber using gravimetry method, ash content using Indonesian national standard (SNI 01-2891-1992) and the amino acid profile were analyzed using Ultra performance liquid chromatography™ (UPLC) method for Serine, glutamic acid, phenylalanine, isoleucine, valine, alanine, arginine, glycine, lysine. Aspartic acid, leucine, tyrosine, proline, threonine and histidine; Liquid chromatography-tandem mass spectrometry (LC-MS/MS) for cysteine and methionine; and High-pressure liquid chromatography (HPLC) for tryptophan. All analyses were conducted at the PT. Saraswanti Indo Genetech (Bogor, West Java, Indonesia).

2.6 Statistical analyses

All growth parameters were analyzed using one-way analysis of variance (ANOVA) to determine the significant differences among treatments followed by Tukey's multiple comparison tests to determine the difference between treatment means in each trial. All statistical analyses were conducted using SAS system (V9.4. SAS Institute, Cary, NC, USA).

3. Results

3.1 Nutritional profile of the feed

Tables 1 and **2** summarize the nutritional information of the commercial feed used in this study based on the information mentioned on the feed bag and the analysis from the test laboratory. Based on the results, diet HP A has a consistent CP level where CP level on the feed bag is 42% and the test results stated the value of CP is 41,7%. Meanwhile, other feed

Table 1. Proximate information on the feed bag and market prices of the commercial feeds used in this study from starter until finisher stage. Average market prices based on the prices of feed on August 12th, 2021. (HP = High protein feed and MP = Medium protein feed).

No	Parameter	Unit	Nutritional Profile of the Diet				National Standard[1]
			HP A	HP B	MP A	MP B	
Starter feed							
1	Protein Content	%	42	40	35	30	32 (min)
2	Crude Fat (min)	%	6	6	6	5	6 (min)
3	Moisture content (max)	%	12	12	11	12	12 (max)
4	Fiber (max)	%	13	4	3,5	4	4 (max)
5	Ash Content	%	3	15	13	11	15 (max)
Grower feed							
1	Protein Content	%	42	40	35	30	30 (min)
2	Crude Fat (min)	%	6	6	6	5	6 (min)
3	Moisture content (max)	%	12	12	11	12	12 (max)
4	Fiber (max)	%	13	4	3,5	4	4 (max)
5	Ash Content	%	3	15	13	11	15 (max)
Finisher feed							
1	Protein Content	%	42	40	32	30	28 (min)
2	Crude Fat (min)	%	6	6	6	5	5 (min)
3	Moisture content (max)	%	12	12	11	12	12 (max)
4	Fiber (max)	%	13	4	3,5	4	5 (max)
5	Ash Content	%	3	15	13	11	15 (max)
Average market price (IDR/Kg of feed)			21.875	19.500	17.807	17.500	

1 National standard (SNI) 7549:2009 – formulated feed for Vannamei (*Litopenaeus vannamei*)

has different results, where protein for HP B, MP A and MP B written on the bag is 40; 35 and 30%, respectively but laboratory analysis revealed that the CP level of HP B, MP A and MP B is 37,31; 31,51 and 32,25%. Other parameters including the moisture content, fiber and ash content still have comparable value with the information written on the label.

3.2 Water quality and growth performance

The water quality and growth performance of the experimental shrimp are presented in **Table 3** and **4.** In general, all water quality parameters are still within the acceptable range to support the optimal growth of Vannamei (Novriadi et al., 2021b). The final body weight (FBW), feed conversion ratio (FCR), thermal growth coefficient (TGC), final biomass, survival rate (SR) and average daily growth differed significantly among the dietary treatment. The FBW, TGC and ADG of shrimp fed with HP B were significantly higher ($P<0.05$) compared to other dietary treatments. The group of shrimp fed with HP B also showed the lowest FCR compared to other dietary treatments. In general, shrimp fed with MP B showed the lowest FBW, TGC, SR and ADG ($P<0.05$) as well as higher FCR compared to other dietary treatments.

3.3 Body carcass analysis

The whole body composition of the shrimp is shown in **Table 5.** Higher whole-body protein and lipid contents were observed in shrimp fed with HP A compared to other treatments. Meanwhile, the highest moisture content was observed in shrimp fed with HP B compared to other treatments. The whole-body mino acid profile was somehow affected by the dietary treatment at the end of the feeding trial.

Discussion

Four commercial feed for Pacific white shrimp *Litopenaeus vannamei*, characterized with high protein level (HP), range from 40 – 42% and medium protein (MP) level ranged from 30 – 35%, were evaluated over a full rearing period

Table 2. Proximate composition (% as is), calories from fat and total calories of feed (KCal 100 g^{-1}), and amino acid profile (% as is) of the commercial feed on the grower stage used in the growth trial. (HP = High protein feed and MP = Medium protein feed).

No	Parameter*	Unit	Nutritional Profile of the Diet			
			HP A	HP B	MP A	MP B
Proximate composition analysis						
1	Protein Content	%	41.7	37.31	32.51	32.25
2	Total Fat	%	7.64	5.49	5.77	5.45
3	Moisture content	%	9.42	10.78	10.5	9.64
4	Carbohydrate	%	31.8	33.87	43.93	44.64
5	Ash Content	%	9.44	12.55	8.32	8.02
6	Crude fiber	%	1.68	2.03	1.95	1.84
7	Calories From Fat	KCal 100 g^{-1}	68.76	49.41	51.66	49.05
	Total Calories	KCal 100 g^{-1}	362.76	334.13	353.42	356.61
Amino acid analysis						
1	L-Cysteine	%	1.32	0.91	0.93	0.72
2	L-Methionine	%	0.69	0.54	0.19	0.26
3	L-Serine	%	2.19	2.14	1.62	1.65
4	L-Glutamic acid	%	4.96	5.26	4.66	4.59
5	L-Phenylalanine	%	2.3	2.52	1.78	1.84
6	L-Isoleucine	%	1.57	1.68	1.26	1.31
7	L-Valine	%	2.09	1.89	1.37	1.43
8	L-Alanine	%	1.84	1.75	1.20	1.29
9	L-Arginine	%	2.51	2.84	2.30	2.17
10	Glycine	%	2.44	2.39	1.70	1.94
11	L-Lysine	%	2.01	1.78	1.23	1.23
12	L-Aspartic Acid	%	2.59	2.62	2.12	2.06
13	L-Leucine	%	3.15	3.17	2.22	2.25
14	L-Tyrosine	%	1.22	1.43	0.96	0.99
15	L-Proline	%	2.31	2.11	1.70	1.81
16	L-Threonine	%	1.76	1.86	1.29	1.33
17	L-Histidine	%	1.12	1.24	0.84	0.87
18	L-Tryptophan	%	0.28	0.26	0.22	0.25

***** All analysis was conducted at the PT. Saraswanti Indo Genetech (Bogor. West Java. Indonesia)

until shrimp grew from 0,003 to 20 – 21 g mean weight during 106 days of the culture period. From the proximate and amino acid composition analysis of the grower feed, we found that crude protein (CP) level becomes the main nutrient component that has significant differences. Based on information written on the label for the grower feed, diet HP B and MP A which is expected to have a CP level of 40 and 35 %, respectively, actually has a CP level of 37,3 and 32,51%, respectively. is The results indicate a significant reduction in CP around 6,75% for HP B and 7,11% for MP A. Interestingly, while diet HP A could maintain the quality, diet MP B actually has a higher CP level on the actual diet (32,25%) compared to the label (30%). Unmatched CP data from both information could cause significant losses to the farmers since protein level play a role to determine the cost and enhance the growth performance of shrimp during the production system.

Table 3. Water quality condition during the growth trial for 106 days

No	Parameters	Unit	Results
1	pH		7.79 ± 0.12
2	Dissolved oxygen	mg L^{-1}	6.14 ± 0.40
3	Temperature	° C	28.73 ± 0.40
4	Salinity	‰	33.23 ± 0.73
5	Ammonia	mg L^{-1}	0.0115 ± 0.0033
6	Nitrite	mg L^{-1}	0.0175 ± 0.0062
7	Nitrate	mg L^{-1}	4.3439 ± 1.2478
8	Phosphate	mg L^{-1}	0.0210 ± 0.0062
6	Nitrite	mg L^{-1}	0.0175 ± 0.0062
7	Nitrate	mg L^{-1}	4.3439 ± 1.2478
8	Phosphate	mg L^{-1}	0.0210 ± 0.0062

The increase in CP level in the current study resulted in a positive effect on survival, growth and feed utilization performance. The good performance of shrimp fed with HP diet indicated that the level of protein, fat and other nutrient components contained in the feed could fulfill the specific nutrient requirement under the practical feeding regime. According to Kureshy and Davis (2002) weigh gain reflected the daily protein intake. Therefore, without paying attention to the nutritional composition of the feed, low protein concepts did not support the maximum weight gain of Vannamei (Kureshy and Davis, 2002). This is in line with the results of the current study where FBW, FCR, TGC and ADG of shrimp fed with MP B are significantly lower compared to HP B and numerically lower than HP A. Despite statistically, groups of shrimp fed with MP A does not have any significant differences in terms of growth performance compared to other dietary treatments. Numerically, MP A also showed the lowest FBW, TGC and ADG compared to HP A and B. Variation in size obtained in the group of MP A at the end of the growth trial makes the responses becomes insignificant.

The use of diets with excessive protein for a particular life stage is likely to underestimate requirements expressed as a percentage of dietary protein (Hauler and Carter, 2001). To increase the cost-efficiency, a low protein diet could be applied together with the ideal protein concept for optimal utilization of protein (NRC, 2011). A study from Huai et al. (2010) suggested that dietary crude protein could be reduced from 41.26 to 35.52% in the diets of shrimp *vannamei* as long as synthetic amino acids were supplemented to ensure the proper bioavailability of lysine, methionine plus cysteine, and threonine within the diet. It was reported that shrimp required at least 34,5; 35,6, and 32,2 % of CP level for juvenile, sub-adult, and adult stages of Pacific white shrimp, respectively to promote growth (Lee and Lee, 2018; Shahkar et al., 2014). In addition, a requirement for limiting amino acids has also been determined using a percentage of amino acid in the dry diets as the unit to support the optimum growth of shrimp, including lysine at the level of 1,64% (Xie et al., 2012), methionine 0,66% (Lin et al., 2015) and threonine 1,18% (Zhou et al., 2013). Shrimp cannot synthesize all amino acids and must acquire several in their diet, through the consumption of protein or a mixture of amino acids (NRC, 2011). Therefore, despite the CP level of the test diet used in this study still within the acceptable range, the lower level of methionine, lysine and threonine in MP feed compared to the HP feed may provide an imbalance in the amino acids (AA) profile and subsequently reduced the growth.

The average daily growth (ADG) of shrimp fed with HP and MP diet in this study is in

Table 4. Performance of the Pacific white shrimp (initial weight ~ 0.003 - 0.005 g) offered commercial diets for 106 days

Diet code	**FBW**	**FCR**[2]	**TGC**	**Biomass**	**SR**	**ADG**
HP A	21.31[ab]	1.09[ab]	0.0823[ab]	7633.33[a]	79.63[a]	0.186[ab]
HP B	21.51[a]	1.08[b]	0.0826[a]	6950.00[b]	71.85[ab]	0.188[a]
MP A	20.65[ab]	1.13[ab]	0.0814[ab]	6666.67[b]	71.78[ab]	0.181[ab]
MP B	20.47[b]	1.14[a]	0.0812[b]	6400.00[b]	69.48[b]	0.179[b]
p-value	0.0211	0.0194	0.0183	0.0006	0.0207	0.0211
PSE[1]	0.2084	0.0108	0.0003	122.1942	1.8382	0.0018

[1] PSE: Pooled standard error.
[2] Values within a column with different superscripts are significantly different based on Tukey's multiple range tests

Table 5. Proximate composition (% as is). calories from fat and total calories of feed (KCal 100 g^{-1}). and amino acid profile (% as is) of the whole body of shrimp *Litopenaeus vannamei* offered commercial diets for 106 days

No	Parameter*	Unit	Nutritional composition			
			HP A	HP B	MP A	MP B
Proximate composition analysis						
1	Protein Content	%	25.58	22.77	24.72	23.82
2	Total Fat	%	0.49	0.22	0.30	0.24
3	Moisture content	%	69.96	73.89	70.59	72.21
4	Carbohydrate	%	1.70	1.57	2.68	2.09
5	Ash Content	%	2.27	1.55	1.71	1.64
6	Calories From Fat	KCal 100 g^{-1}	4.41	1.98	2.70	2.16
7	Total Calories	KCal 100 g^{-1}	113.53	99.34	112.30	105.8
8	Crude fiber	%	<0.02	<0.02	<0.02	<0.02
Amino acid composition analysis						
1	L-Cysteine	%	0.54	0.54	0.70	0.54
2	L-Methionine	%	0.42	0.34	0.45	0.42
3	L-Serine	%	1.15	1.00	1.01	1.15
4	L-Glutamic acid	%	3.12	2.94	3.25	3.12
5	L-Phenylalanine	%	1.53	1.23	1.45	1.53
6	L-Isoleucine	%	1.09	0.99	0.99	1.09
7	L-Valine	%	1.13	1.02	1.03	1.13
8	L-Alanine	%	1.25	1.23	1.26	1.25
9	L-Arginine	%	2.82	2.29	2.67	2.82
10	Glycine	%	1.91	1.77	1.56	1.91
11	L-Lysine	%	1.44	1.41	1.53	1.44
12	L-Aspartic Acid	%	1.71	1.63	1.92	1.71
13	L-Leucine	%	1.90	1.74	1.75	1.90
14	L-Tyrosine	%	1.04	0.84	0.99	1.04
15	L-Proline	%	1.94	1.79	1.90	1.94
16	L-Threonine	%	1.23	1.05	1.03	1.23
17	L-Histidine	%	0.80	0.65	0.74	0.80
18	L-Tryptophan	%	0.18	0.19	0.19	0.18

* All analysis were conducted at the PT. Saraswanti Indo Genetech (Bogor. West Java. Indonesia).

the range of 0,179 – 0,188 g day^{-1}. These numbers were the similar with the data from production characteristics of intensive shrimp *L. vannamei* in Vietnam, with an average density of 109,14 shrimp m^{-2}, has resulted in median ADG of 0,19 g day^{-1} (Thakur et al., 2018). In Indonesia, average ADG was reported around 0,17 – 0,20 g day for shrimp cultured intensively (Arsad et al., 2017; Lailiyah et al., 2018). The lowest ADG in this study was found in the group of shrimp fed with MP B that also had the lowest CP level compared to other dietary treatment. This may indicate that a proper level of protein that could exceed degradation is needed to have better protein deposition to support the live weight gain in shrimp.

Protein deposition in organisms is determined by specific templates, including the endogenous (genetic and life stage) and also exogenous (environment and diet) factors (NRC, 2011). Studies have also shown that the whole-body amino acid composition is minimally affected by the body size of the aquatic organisms (Kaushik, 1998). Looking at the data of whole-body composition of the shrimp at the end of the growth trial, the lower level of protein obtained in shrimp body fed with HP B that has better nutritional profile and growth performance probably due to the inappropriate drying techniques as the moisture level of HP B (73,89%) is higher than other dietary treatment. According to Akonor et al. (2016) different approaches of drying process may affect the nutritional quality of shrimp meat differently.

Based on the market prices, HP A was the highest and MP B was the cheapest feed used in this growth trial. The feed cost also affects the nutritional profile where the group of MP feed had the lowest lysine and methionine level compared to the HP feed. Lysine is commonly the first limiting amino acids in feed, particularly those formulated with high inclusion levels of plant-based protein sources or with ingredients processed under harsh conditions (NRC, 2011). Meanwhile, lack of methionine will results in poor growth and feed efficiency (NRC, 2011). Considering the better growth performance obtained by using HP feed, cost efficiency and profitability still can be achieved. However, with small differentiation, especially with MP A, there is still room to re-formulate the diet formulation with a cost-effective protein levels that still fulfills the specific nutrient requirement of the shrimp. For this reason, further analysis evaluating all spectrum of production budget with data gathering from multiple points such as the feed cost, growth performance and market prices of shrimp at the end of the growth trial are needed to provide more choices of feed to the shrimp producers.

4. Conclusion

The results of this study provide essential information about the importance of monitoring and evaluation to maintain the quality of the commercial feed available in the market. High protein feed provided better nutritional value, especially for lysine, methionine and threonine compared to the medium feed and eventually could provide better growth to the shrimp. The FBW, FCR, TGC, SR and ADG values between the high protein group and medium protein A (MP A) were not statistically different, therefore, re-formulation of shrimp feed diet by providing a cost-effective diet is important to support the sustainability of the shrimp industry.

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