Aquaculture

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Development of economical feed for Pacific White shrimp *(Penaeus vannamei)*

The development of economical feed for Penaeus vannamei has become a major focus in modern shrimp aquaculture, as feed represents the largest operational cost—often exceeding 50% of total production expenses. To reduce feed cost without compromising growth and survival, researchers and feed manufacturers are exploring the use of alternative protein sources such as plant-based ingredients (soybean meal, corn gluten, and fermented plant protein) and by-products from agriculture or fisheries (fishmeal replacers, poultry by-product meal, and insect meal). Advances in feed formulation, enzyme supplementation, and nutrient digestibility studies have enabled the reduction of expensive marine ingredients while maintaining feed efficiency and health performance of shrimp.

One alternative ingredient that can be used to replace expensive raw materials or animal protein is Distillers Dried Grains with Soluble (DDGS). Currently, DDGS is increasingly recognized as a promising alternative ingredient for economical feed formulation in Penaeus vannamei culture. Derived as a by-product of ethanol production from corn, DDGS contains approximately 25–35% crude protein, 8–12% lipid, and valuable nutrients such as vitamins, minerals, and digestible carbohydrates. Its relatively low cost and consistent availability make it attractive for partial fishmeal replacement in shrimp feeds. However, the presence of fiber and a variable amino acid balance (notably low lysine and methionine) may limit its inclusion level unless it is properly supplemented with synthetic amino acids or enzyme additives to enhance nutrient utilization.

For this, a strategy is needed to formulate feed by balancing all nutrient requirements, including the availability of limiting amino acids, to ensure optimal growth, feed efficiency, and health while minimizing feed cost and environmental waste. Other than supplementation process, this nutritional balancing process can be achieved by combining DDGS with other alternative raw materials to obtain precise proportions of protein, lipids, carbohydrates, vitamins, and minerals, supporting tissue development, immune function, and energy metabolism. The strategy involves adding several functional additives, such as attractants, enzymes, probiotics, and immunostimulants like protease or nucleotides, to maintain shrimp performance even in low-cost diets.

To determine whether economical feed can be developed by replacing premium raw materials with economical ones, an observation was conducted using DDGS to substitute soybean meal in shrimp feed

Table 1. Ingredient composition and formulation cost of experimental diets containing four graded levels of corn distillers dried grains with solubles (DDGS) for trial controlled and using an open-pond system.

Ingredient (%)	Diet			
	D0	D5	D10	D15
Soybean meal	25.0	22.5	20.0	17.5
Poultry by-product meal	20.3	20.3	20.3	20.3
Fishmeal	8.0	8.0	8.0	8.0
Corn DDGS	0.0	5.0	10.0	15.0
Tuna hydrolysate	2.0	2.0	2.0	2.0
Squid liver powder	6.0	6.0	6.0	6.0
Wheat flour	31.9	29.3	26.8	24.2
Soy lecithin	1.5	1.5	1.5	1.5
Fish oil	1.0	1.0	1.0	1.0
Monocalcium phosphate	1.8	1.8	1.8	1.8
L-lysine	0.00	0.04	0.09	0.14
DL-methionine	0.19	0.18	0.17	0.17
L-threonine	0.08	0.08	0.08	0.09
Mineral premix	1.20	1.20	1.20	1.20
Vitamin premix	0.41	0.41	0.41	0.41
Magnesium sulphate	0.35	0.35	0.35	0.35
Choline chloride	0.20	0.20	0.20	0.20
Antimol	0.12	0.12	0.12	0.12
Formulation cost (IDR/kg)*	10.142	10.037	9.933	9.833

Note: D0 = no inclusion of DDGS; D%5 = 5 inclusion of DDGS; D%10 = 10 inclusion of DDGS; and D%15 = 15 inclusion of DDGS.

formulations with a nutritional balancing strategy. The observation was conducted in a controlled phase using hapa nets installed in commercial ponds specifically for vannamei shrimp production. The feed formulation and growth rates can be seen in Tables 1, 2, and 3.

In the feed formulation (Table 1), supplementation is carried out, especially for the three limiting amino acids — lysine, methionine, and threonine — to rebalance the amino acid profile when soybean meal is substituted with DDGS.

Table 2. Growth, feed intake, feed conversion and feed cost per gain of Pacific white leg shrimp from two separate feeding trials using aquaria tanks. The mean value consists of ten and eight replicates from trial 1 and 2, respectively.

Diet	IBW[1] (g)	FBW[2] (g)	TGC[3]	FI[4] (g/shrimp)	FCR[5]	FCG[6] (IDR/kg gain)	Survival (%)
Trial 1 period is 52 days							
D0	1.04	10.17	0.077	16.83	1.85	18.783	86.79
D5	1.06	10.90	0.080	16.85	1.72	17.289	89.42
D10	1.03	10.30	0.078	16.81	1.82	18.077	90.17
D15	1.03	10.17	0.078	17.17	1.89	18.541	90.75
PSE[9]	0.0126	0.2367	0.0011	0.2220	0.0447	445.5	2.3956
p-value	0.2573	0.0856	0.2257	0.5969	0.0525	0.0822	0,5985
Trial 2 period is 84 days							
D0	5.20	18.51	0.035	27.56	2.08	21.056	67.50
D5	5.19	19.29	0.036	28.20	2.00	20.063	70.00
D10	5.17	18.90	0.036	28.91	2.11	21.003	70.75
D15	5.19	19.49	0.037	29.90	2.10	20.684	66.00
PSE	0.0749	0.3741	0.0007	0.8491	0.0707	703.2	6.6299
p-value	0.9919	0.2342	0.3009	0.2251	0.6192	0.7079	0.7253

Research conducted in a controlled and open-pond system has shown that economical feed production for Vannamei shrimp can be achieved with affordable ingredients to replace the expensive ingredients as long as the diet is well formulated and pays attention to digestibility and nutritional balance that meets the nutritional requirements precisely to support optimal growth, health, and feed efficiency. In addition, this research found that DDGS can be used at up to 15% concentration without negatively impacting shrimp growth. Another happy story, as shown in Table 1, feed costs can be reduced by up to 3.05%. Reducing feed costs as the largest variable cost really helps farmers to increase profits and competitiveness of the products in the (global) market.

The development of economical feed for Penaeus vannamei requires a step-by-step strategy that balances cost reduction with nutritional adequacy and growth performance. The first step involves identifying and evaluating alternative protein sources to partially replace expensive ingredients such as soybean meal and other animal protein. Locally available plant proteins (palm kernel meal), agricultural by-products, and novel ingredients like single-cell proteins or insect meals can

Table 3. Growth performance of pacific white shrimp Penaeus vannamei (Mean initial weight 1.06±0.01 g) fed experimental diets for 90 d in commercial ponds. Values represent the mean of ten replicates.

Diet code	Final Biomass (g)	FBW (g)	Survival (%)	PWG[7] (%)	FCR	TGC	ADG
DO	12089.00^{b}	19.861^{b}	84.55	1769.27^{b}	1.245^{a}	0.0669^{b}	0.214^{b}
D5	12282.00^{a}	20.187^{a}	84.50	1799.95^{a}	1.224^{b}	0.0676^{a}	0.217^{a}
D10	12352.00^{a}	20.252^{a}	84.72	1806.08^{a}	1.219^{b}	0.0677^{a}	0.218^{a}
D15	12074.00^{b}	19.848^{b}	84.49	1768.05^{b}	1.246^{a}	0.0670^{b}	0.214^{b}
p-value	<0.0001	<0.0001	0.9689	<0.0001	<0.0001	<0.0001	<0.0001
PSE[9]	80.9602	0.0964	0.6572	9.0783	0.0064	0.0002	0.0011

Note: 1 IBW = Initial body weight; 2 FBW = Final body weight; 3 TGC = Thermal growth coefficient; 4 FI = feed intake; 5 FCG = Feed cost gain; 7 PWG = Percentage weight gain; 8 ADG =Average daily growth in gram per day, 9 PSE = Pooled standard error

Figure 1. Visual of experimental feed

be incorporated after assessing their digestibility, amino acid profile, and absence of anti-nutritional factors. The second step is applying the ideal protein concept to ensure amino acid balance while minimizing excessive crude protein inclusion. In the third step, feed additives such as enzymes, probiotics, and organic acids are introduced to enhance nutrient utilization and digestibility, allowing greater flexibility in using low-cost ingredients. The fourth step focuses on improving feed processing conditions, including pellet stability, moisture content, and particle size, to ensure efficient nutrient delivery and minimize leaching losses. Finally, developed economical feeds will not have a positive impact without proper and precise feeding management. Therefore, adjustments to feed management using economical feeds are necessary to ensure that, while generating profits, the process also avoids negative effects to the environment. By integrating these steps systematically, feed producers can formulate cost-effective diets that maintain shrimp health, growth, and sustainability in intensive culture systems.

Figure 2. Shrimp after 90 days feeding period using an open-pond system