INVESTIGATION OF DUCK MEAL AS A CIRCULAR ECONOMY-BASED SUBSTITUTE FOR FISH MEAL IN DIETS OF WHITE SHRIMP *Penaeus vannamei*

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Abstract

Duck meal derived from spent laying ducks was evaluated as a sustainable alternative protein source to replace fish meal in diets for white shrimp, *Penaeus vannamei*. The proximate composition, amino acid profile, and fatty acid composition of duck meal were analyzed and compared with those of fish meal. A 56-day feeding trial was conducted to determine the effects of graded levels of fish meal replacement (0, 20, 40, 60, and 80%) with duck meal on growth performance, feed utilization, nutrient digestibility, body composition, and disease resistance.

Duck meal contained high levels of crude protein and lipid and exhibited a relatively balanced essential amino acid profile, although it was deficient in long-chain n-3 highly unsaturated fatty acids. Growth performance, feed efficiency, survival, and muscle composition of shrimp were not significantly affected when fish meal was replaced by up to 60%. Broken-line regression analysis estimated the optimal replacement level at 59.5% (Fig. 1). However, an 80% replacement level significantly reduced growth and protein utilization, likely due to lower protein digestibility and insufficient dietary n-3 HUFA. No significant differences in mortality were observed following *Vibrio alginolyticus* challenge among treatments.

These results indicate that duck meal, as a value-added by-product within a circular economy framework, can effectively replace up to 60% of fish meal in diets for *P. vannamei*. Nevertheless, nutritional supplementation may be necessary to improve performance at higher inclusion levels.

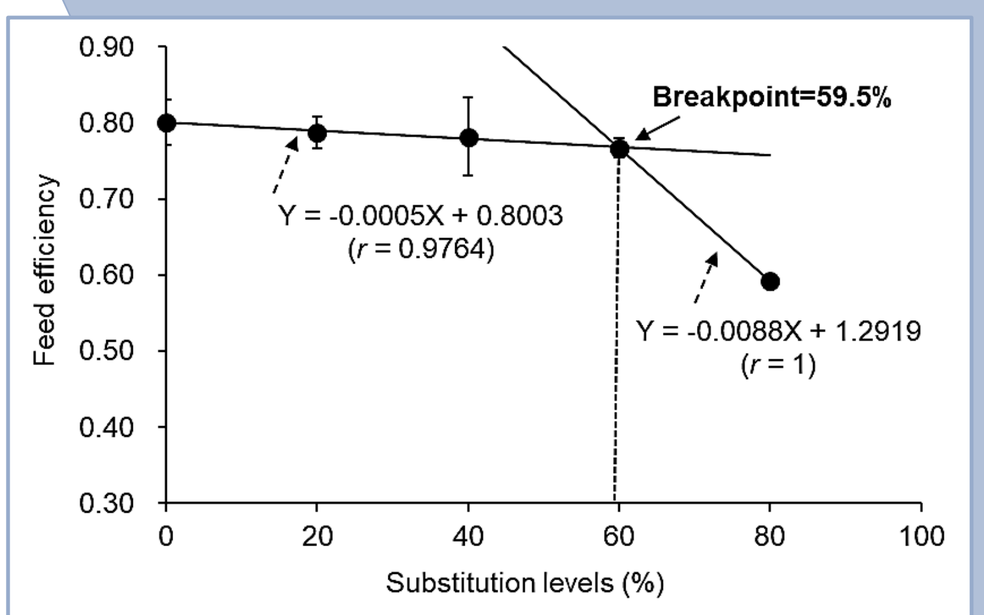


Fig. 1. Broken-line regression analysis of feed efficiency in white shrimp fed diets with increasing levels of fish meal substitution by duck meal.

Results

Table 1. Growth performance of shrimp fed with the experimental diets for 56 days. Values are presented as mean ± SE (n = 719 3), where n represents the number of tanks. Different superscript letters within the same row indicate significant differences 720 among treatments ($p < 0.05$)

	Experimental diets				
	FM	WDM20	WDM40	WDM60	WDM80
Final weight (g)	5.42±0.14^{a}	5.57±0.19^{a}	5.56±0.19^{a}	5.49±0.29^{a}	4.23±0.41^{b}
Survival (%)	82.2±1.6	83.7±2.4	85.2±0.9	83.0±2.4	83.0±4.0
Percentage of weight gain (%)	900.1±12.6^{a}	947.2±18.7^{a}	962.8±25.6^{a}	921.8±25.1^{a}	683.9±42.1^{b}
Feed conversion ratio	1.25±0.05^{b}	1.27±0.03^{b}	1.29±0.08^{b}	1.30±0.02^{b}	1.69±0.06^{a}
Production (g m^{-3})	133.54±1.69^{a}	139.83±2.50^{a}	141.91±3.41^{a}	136.44±3.35^{a}	104.67±5.62^{b}

Table 2. Feed utilization efficiency and apparent nutrient digestibility of shrimp in this study. Values are presented as mean 727 ± SE (n = 3), where n represents the number of tanks. Different superscript letters within the same row indicate significant 728 differences among treatments ($p < 0.05$)

Parameters	Experimental diets				
	FM	WDM20	WDM40	WDM60	WDM80
Protein efficiency ratio	2.16±0.08^{a}	2.13±0.06^{a}	2.11±0.14^{a}	2.07±0.03^{a}	1.60±0.06^{b}
Apparent net protein utilization (%)	36.67±1.38^{a}	36.56±0.96^{a}	34.85±2.30^{a}	34.70±0.58^{a}	26.07±0.95^{b}
Dry matter apparent (%)	91.32±2.27^{a}	91.02±1.85^{a}	85.27±1.54^{ab}	84.90±2.94^{ab}	80.37±0.39^{b}
Apparent nutrient digestibility (%)					
Crude protein	95.20±1.46^{a}	94.80±0.83^{a}	94.17±1.70^{ab}	93.48±1.15^{ab}	89.06±1.34^{b}
Crude lipid	93.70±1.46	93.92±1.02	92.25±1.30	91.70±1.82	91.28±1.33

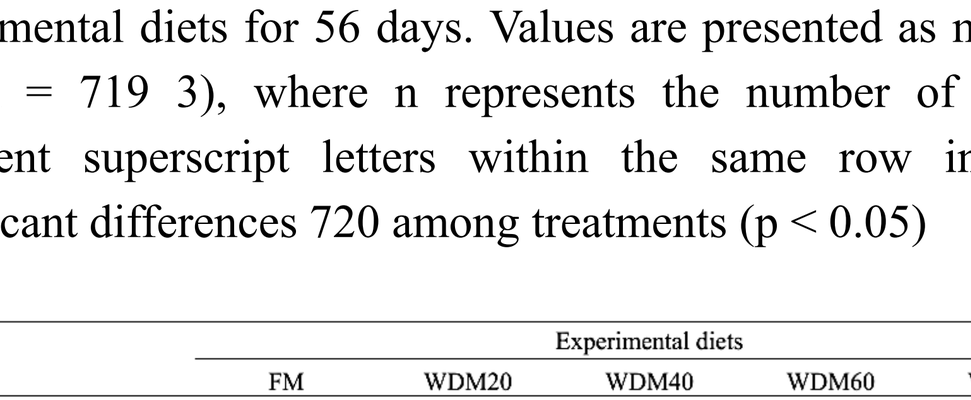


Fig. 2. Growth of shrimp fed the different test diets. Values are expressed as mean ± 731 SE. Different superscript letters at the end of the trial indicate significant differences 732 among dietary treatments ($p < 0.05$). n=3.

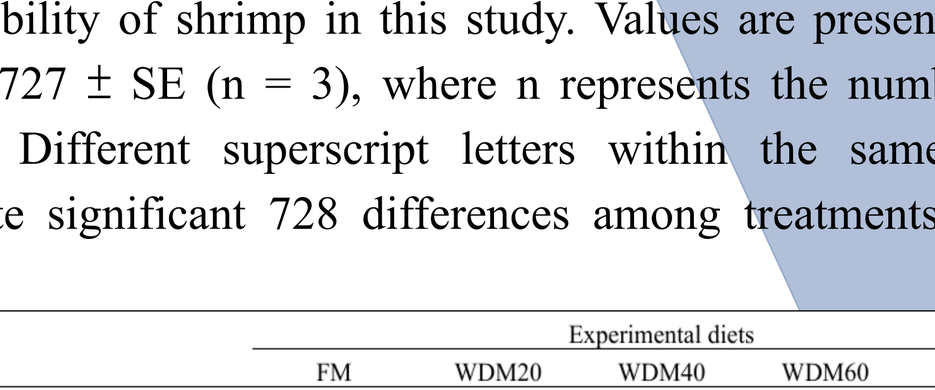


Fig. 3. Cumulative mortality of shrimp fed experimental diets containing different 741 levels of duck meal for 56 days and subsequently challenged with Vibrio alginolyticus. 742 Values are presented as mean ± SE (n=3). No mortality was observed in the 743 unchallenged control group, and no significant differences were detected among the 744 challenged groups ($p > 0.05$).

Conclusion

This study demonstrated that duck meal contains high protein and lipid levels and provides a relatively balanced essential amino acid profile, indicating its strong potential as an alternative protein source in aquafeeds. In the feeding trial, replacing fish meal with duck meal up to 60% did not negatively affect growth performance, feed utilization, muscle proximate composition, or disease resistance of white shrimp, and the optimal replacement level was estimated at 59.5% based on the final weight and feed conversion ratio. However, a higher replacement level (80%) significantly reduced growth and protein utilization, which was likely associated with reduced protein 19 digestibility together with a decreased supply of marine-derived lipids and long-chain n-3 HUFAs. From a resource utilization perspective, if the annual biomass of spent laying ducks (2,358 metric tons) were fully processed, it would yield approximately 712.8 metric tons of duck meal, based on the processing yield determined in this study. Nevertheless, the practical application of duck meal may be influenced by factors not fully addressed in the present study, including processing conditions, raw material composition, and the digestibility of duck meal as a standalone ingredient. Therefore, while duck meal shows promise as an alternative protein source, further research is required to optimize its nutritional quality and application in aquafeed formulations.