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Full length Research

Assessment of hen-day lay, egg quality indices and economics of production in replacing fish meal with shrimp waste

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ABSTRACT: This research assessed the effects of feeding Shrimp Waste Meal (SWM) in place of fish meal, on the performance characteristics and egg quality indices in layers. Ninety Point of Lay (POL) Isa Brown pullets were randomly allotted to five dietary treatments in a completely randomised design (CRD). Each treatment of 18 POL birds was replicated 3 times with 6 birds per replicate per treatment. The effects of the treatments were evaluated in a twelve-week study in which shrimp waste meal (SWM) replaced fish meal at 0% (Treatment 1), 25% (Treatment 2), 50% (Treatment 3), 75% (Treatment 4), and 100% (Treatment 5) levels of inclusion. Birds on treatment four (T4) which contained 75% of shrimp waste meal and 25% fish meal exhibited significantly ($p<0.01$) higher performance than those on the control diet and the other treatments. Non-significant ($P>0.05$) differences were obtained in egg quality parameters (Haugh unit, Yolk Index and Albumen Index), except egg weight, which was significantly ($p<0.05$) higher in T4 (75% SWM and 25% FM) than the other dietary treatments. Considering egg production as a function of the cost of feed consumed, the replacement value of the diet containing 75% SWM significantly ($p<0.05$) exhibited the least cost (₦80.53/egg produced) compared to all the other treatments. It was therefore concluded that shrimp waste meal could best replace fish meal in laying hen diets up to 75% for the highest feed conversion efficiency, egg quality parameters, and least cost value, and it was so recommended.

Keywords: Albumen index, Haugh unit, layers, shrimp waste, yolk index.

INTRODUCTION

Chicken eggs constitute a readily available source of animal protein which is far more accessible than other foodstuff such as chicken, beef and mutton. Its usefulness in the growth and development of children, contribution to brain functioning and the development of intelligent quotient (IQ) in growing children cannot be overemphasized. According to AgeRight (2021), eggs constitute the top source of choline an important factor for cellular growth and maintenance, as well as the enhancement of memory. Eggs also contain vitamin D, which is essential for bone, teeth, immune health, lutein and zeaxanthin which are antioxidants (Ivey 2019). Binuomote *et al.* (2008) have also submitted that egg can be an alternative to meat, owing to its completeness in terms of its amino acid content which is proportionate to the body's requirements for the growth and repair of body tissues. The retinol content of eggs is highly essential for eyesight as well as the protection of the body against skin infections.

However, despite these obvious nutritional and health benefits, the high prices of feed ingredients especially animal protein sources which is often times fishmeal, have made the consumption of eggs a luxury reserved only for the wealthy in developing countries. The high cost of fishmeal and its inclusion in poultry diets accounts for a large chunk of the total cost of feed production. This high cost is further aggravated by the importation of fishmeal from other countries to Nigeria, with the associated foreign exchange implications. The attendant importation taxes such as landing costs, have to be recovered by importers who have to recover their capital along with interest. The chain reaction resulting from these costs incurred by marketers culminates in the high cost of eggs in the markets and of course, its reduced consumption. As observed by Fanimo *et al.* (1996), Agunbiade *et al. (*2004), and Aktar *et al.* (2011), shrimp waste meal can replace fish meal in broiler chicken feed up to 25%, 50% and 66%, indicating that it has great potentials as an alternative protein source of animal origin (Rosenfeld *et al.(*1997) and Agunbiade *et al.* (2004). The by-product has been incorporated into livestock feed as a result of its high nutritional value. Shrimp waste meal is particularly rich in lysine and is palatable, having a pleasant aroma that makes it an ideal supplement for cereals (Fanimo *et al.* (1996). Gernat (2001) observed that shrimp meal can be used as a sole source of protein in starter and growing rations, adding that better growth is obtained where more than one protein source is used. However, there is a paucity of information regarding shrimp waste meal usage in layers' diets, especially in Nigeria. The value chain of shrimp waste meal usage in layers' feeding can be far reaching, cutting across waste management, provision of quality animal protein, reduction of total cost of poultry production, increased production and efficiency of feed conversion and ultimately making egg consumption and its attendant health benefits, more accessible to all and not just to a privileged few. It is on this background that the present research was undertaken to evaluate the effects of the use of shrimp waste meal in layers' diets on graded levels as a replacement for fish meal, on the performance, economics of production, as well as egg quality indices of layers.

MATERIALS AND METHODS

Experimental site

The study was carried out at the Poultry Unit of the Akwa Ibom State University Teaching and Research Farm, Obio Akpa Campus. Obio Akpa is in Northeastern part of Oruk Anam Local Government Area in Akwa Ibom State, Nigeria, lying between latitudes 4°32'N and 5°33'N and longitudes 7°25'E and 8°25'E (Wikipedia, 2008).

Collection, processing and storage of shrimp waste meal

Waste from smoke-dried shrimps was collected from two fishing communities: Uta Ewa and Market Bridge Head, both in Ikot Abasi Local Government Area of Akwa Ibom State of Nigeria. The waste collected was sun-dried, sorted and milled then stored in jute bags away from moisture and mould.

Experimental birds, management and design

Ninety (90) Point of Lay (POL) Isa Brown pullets at nineteen weeks of age were raised on a deep litter house with optimum floor spacing. The birds were subjected to standard routine management activities involving sanitation, pest and disease control as well as nesting. The Completely Randomized Design (CRD) was used to allocate 6 birds each, to each of the 3 Replicates of the 5 dietary treatment groups. 1 kg of feed was served in 2 instalments of 500 g daily, while water was given *ad libitum.*

Experimental diets

The shrimp waste meal (SWM) and fish meal (FM) used for the experiment were subjected to proximate analysis and the information from the proximate fractions obtained was used to formulate the test diets. Five (5) different levels of inclusion of the test ingredient (SWM), made up the dietary treatments. The groups were designated T1 to T5 thus: T1: 0% SWM: 100%FM, T2: 25%SWM and 75%FM, T3: 50% SWM and 50%FM, T4: 75%SWM and 25%FM, T5: 100%SWM (0%FM) as shown in Table 1. Apart from the varying levels of SWM and FM used, all other feed ingredients remained constant for the 5 differently formulated diets used in the study.

Data collection

Proximate analysis

The proximate composition of the feed ingredients used were determined using the methods of AOAC (2010).

Determination of amino acid profile

The amino acid profiles of the test ingredients, shrimp waste meal and fish meal were determined using the Applied Biosystems PTH Amino Acid Analyzer, according to procedures specified by AOAC (2006).

Percentage hen-day production

Eggs were collected from each replicate 3 times daily (9 am, 12.00 noon and 3.00 pm). Total daily collections were collated per treatment per day, the average of production for each day was recorded for 84 days of the experiment,

Table 1. Percentage Ingredient composition, crude protein and energy levels of experimental layer diets.

Ingredients	T1	T2	T3	T4	T5
Yellow maize	52.50	52.50	52.50	52.50	52.50
Wheat offal	15.00	15.00	15.00	15.00	15.00
Soyabean meal	15.00	15.00	15.00	15.00	15.00
Fish meal	8.00	6.00	4.00	2.00	0.00
Shrimp waste meal	0.00	2.00	4.00	6.00	8.00
Limestone	5,00	5,00	5,00	5,00	5,00
Bone meal	2.50	2.50	2.50	2.50	2.50
Vit./min. premix	0.25	0.25	0.25	0.25	0.25
Palm oil	0.75	0.75	0.75	0.75	0.75
Salt	0.25	0.25	0.25	0.25	0.25
Methionine	0.40	0.40	0.40	0.40	0.40
Lysine	0.25	0.25	0.25	0.25	0.25
Toxin binder	0.10	0.10	0.10	0.10	0.10
Total (%)	100.00	100.00	100.00	100.00	100.00
Crude protein (%)	16.12	16.22	16.33	16.43	16.54
ME (Kcal/kg)	2831.6	2834.1	2837.9	2841.6	2839.5

T1: 0% Shrimp Waste Meal: 100%Fish Meal, T2: 25%SWM:75%FM, T3: 50%SWM:50%FM, T4: 75%SWM: 25%FM, T5: 100% SWM:0%FM.

and the average weekly production for 12 weeks was taken therefrom. Data on eggs collected daily were used to determine the percentage hen-day production by dividing the total number of eggs laid, by the number of birds that are alive, and the result multiplied by one hundred. Values obtained were recorded daily and treatment means calculated weekly.

Feed intake: The feed consumed by the three replicates of the 5 treatments was determined daily. This was done by subtracting the left over feed in the morning from the initial amount of feed served the previous day. The means of feed intake per replicate was taken at the end of the experiment and the data was used to calculate the feed consumption per treatment.

Feed conversion ratio: The feed conversion ratio was calculated by dividing the total quantity of feed consumed by the total weight of eggs laid within the period. This was done for the five (5) treatments using data on daily feed intake against egg production of the following day.

Egg weight: The weight of individual eggs was taken and the totals for each replicate were taken and recorded at the end of each production day.

Egg quality parameters: The egg quality parameters: Haugh Unit (Haugh, 1937), Yolk Index (Sauter *et al.,* 1951) and Albumen Index (Heiman and Carver, 1936) for each of the 15 replicates of the study were determined at the end of each week of production for the 12 weeks of the experimental period, using already established procedures.

RESULTS AND DISCUSSION

Proximate composition of shrimp waste meal (SWM)

The proximate fractions obtained from the analysis of shrimp waste meal and fish meal used for the study are presented in Table 2**.** The moisture content of 10.89% obtained in SWM, was slightly higher than that (10.17%) of fish meal, and was similar to the values (10.5%) and 11.0%), reported by Gernat (2001) and Brito *et al.* (2020a) respectively. It was slightly higher than the values (7.2% and 9.02) which were reported by Oduguwa *et al.* (2005) and Carranco-Juregal (2006), respectively. However, the studies of Rahman and Koh (2017) showed a much higher value (44.5%).

The crude protein content (52.50%) obtained for shrimp waste meal was higher than that of fish meal (47.25%) but similar to the 52.7% reported by Gernat (2001), while values reported by Carranco-Juregal (2006), Brito *et al.,(*2020), and Rahman and Koh (2017), 36.072%, 32.60% and 44.5%, respectively were lower than what was obtained in this study.

The ash value (16.7%), was much higher than that (0.80%) of fish meal and slightly higher than that (14.0%) of Fanimo *et al.* (2000), as compared to those (19.6% and 18.5%) of Khan *et. al*. (2013) and Oduguwa *et al*. (2005) respectively, which were slightly higher, however, Brito *et al*. (2020a) reported a much higher value (47.20%).

The ether extract (1.60%) obtained in SWM was much lower than that (14.07%) of fish meal, and slightly lower than that (2.08%) of Gernat (2001), slightly lower (3.2%) than that of Rahman and Koh (2017), but the values (39.90%

Table 2. Proximate composition of shrimp waste meal and fish Meal.

Fraction	Composition (%)	
	Shrimp Waste Meal	Fish Meal
Moisture	10.89	10.17
Crude protein	52.5	47.25
Ash	16.70	0.80
Ether extract	1.60	14.07
Crude fibre	16.33	6.60
NFE	1.98	21.11

Table. 3. Amino acid composition of shrimp waste meal and fish meal in test diets (g/100g).

Amino acid	Shrimp waste meal	Fish meal
Histidine	3.63	2.00
Isoleucine	3.68	3.63
Leucine	6.98	6.31
Lysine	6.26	5.43
Methionine	2.64	2.38
Phenylalanine	4.46	3.99
Threonine	3.84	3.38
Tryptophan	0.80	0.61
Valine	4.01	3.89
Proline	3.39	3.24
Arginine	6.46	4.53
Tyrosine	2.68	2.15
Cystine	0.89	0.68
Alanine	4.55	4.40
Glutamic acid	12.37	10.72
Glycine	6.11	4.90
Serine	3.74	3.30
Aspartic acid	8.55	7.45
Norleucine	Internal standard	Internal standard

Applied bio system PTH amino acid analysis.

and 26.80%) of Brito *et al.* (2020b) and Fanimo and Oduguwa (1999) respectively, were much higher.

The NFE value (1.98%) was very much lower than that (21.11%) of the fish meal but comparatively slightly higher than the value (1.63%) reported by Nwanna (2003), lower than those (31.68%, 7.53%, and 7.0%) of Fanimo and Oduguwa (1999), Khempaka *et al*. (2011), and Mounica *et al*. (2019), respectively.

The results from SWM revealed 16.33% crude fibre which was much higher than the 6.60% observed in fish meal, and higher than the values (12.3%, 11.38%, and 6.81%) reported by Fanimo and Oduguwa (1999), Gernat(2001), and Abun (2022), respectively.

Amino acid profiles of the experimental shrimp waste meal and fish meal

The results of the evaluation of the amino acid composition of shrimp waste meal compared with the fish meal used in this study are presented in Table 3. The essential amino acids in SWM were higher than those found in fish meal.

The value (2.00 g/100g) of histidine, obtained in this study, was slightly higher than that (1.59 g/100g) obtained by Brito *et al*. (2020b) but lower than the level (6.50 g/100g) reported by Belandria and Morillo (2013). The value (3.68 g/100g) of isoleucine revealed a higher content than that (1.212 g/100g) of Belandria and Morillo (2013) while that

Table 4. Effect of shrimp waste meal on performance characteristics of laying hens.

Parameters	Treatments					SEM	p-value	LOS
	1	2	3	4	5			
Av. Daily Feed intake/ Bird	134.92[b]	130.08[d]	122.88[e]	132.20[c]	139.78a	1.50	0.002	**
HDP (%)	86.02[ab]	86.17[ab]	80.95[bc]	88.16[a]	79.09[c]	0.93	0.010	*
FCR	2.85[ab]	2.78[ab]	2.80[ab]	2.69[a]	3.23[b]	0.06	0.009	**
Average Egg weight	58.71[a]	56.18[b]	57.20[ab]	57.13[ab]	57.34[ab]	0.28	0.004	**

(3.86 g/100g) of Brito *et al.* (2020a) was almost the same. The lysine and methionine values (6.26g /100g and 2.64 g/100g), respectively, obtained in this study were slightly lower than those (6.98 g/100g and 4.35 g/100g) of Belandria and Morillo (2013). But Brito *et al*. (2020b) revealed much higher values (19.30 g/100g, 16.70 g/100g and 5.40g/100g) for lysine, methionine and isoleucine, respectively.

The phenylalanine value (4.46 g/100g) of this research was lower than those (6.71 g/100g and 22.90 g/100g) reported by Belandria and Morillo (2013) and Brito *et al.* (2020b), respectively. The threonine, tryptophan and valine levels (3.84 g/100g, 0.80 g/100g and 4.01 g/100g) obtained in this study, were all lower than those (10.80 g/100g, 8.19 g/100g and 15.10 g/100g) revealed by Brito *et al*. (2020b).

Performance characteristics of laying hens fed shrimp waste meal-based diets

Parameters defining the performance of layers fed graded levels of shrimp waste replacement for fish meal are shown in Table 4.

Percentage Hen-day Production (%HDP)

The effects of levels of inclusion in shrimp waste meal recorded significant ($p<0.05$) differences among the treatment groups. The values ranged between 79.09% for T5 (100%SWM) to 88.16% for T4 (75% SWM replacement). The HDP recorded for T4 was significantly ($p<0.05$) higher than the values recorded for T3 (50%SWM) and T5 (100% SWM) but not significantly ($p>0.05$) different from T1 (0%SWM) and T2 (25% SWM). The higher HDP in T4 can be attributed to the higher level (52.5) of crude protein in the shrimp waste meal used as compared to that of fish meal (47.25%). It should also be noted that there was no significant ($p>0.05$) difference between the percentage hen-day production of birds on T1 (100%FM;0%SWM) and T2 (75%FM:25%SWM). These results indicated the comparative superiority of the shrimp waste meal over the fish meal sample used in this study and also, Gernat (2001) observed that better performance in poultry is obtained when more than one protein source is used, instead of just one. Another possibility as to the higher hen-day production found at a higher inclusion level (75%), is the high content of lysine in shrimp waste meal, as the study of Fanimo *et al.* (1996) revealed that SWM is particularly rich in lysine, an essential amino acid. The fact that the highest percentage of hen-day production was obtained from a diet containing 75% replacement of fish meal by shrimp waste meal, reveals its potential for economic boost in layer production.

Feed intake

The results showed that the effects of dietary treatments on the daily feed intake of laying hens were statistically significant ($p<0.01$). There were significant differences in the feed intake across treatments. Laying hens fed T3 (50%SWM:50%FM) had the lowest (122.88 g) feed intake, while those on T4 (75%SWM:25%FM) had the highest 132.209 g. Birds on T5 (100%SWM:0%FM) showed the highest (139.78 g) level of feed intake. The increased feed intake at high shrimp waste inclusion (100%), is a factor of the palatability and possession of a pleasant aroma by shrimp waste meal (Fanimo *et al.,* 1996). The findings for feed intake in the present study agreed with that of Abun *et al.* (2019), who observed a direct proportionality between feed consumption rate, and the replacement value of fish meal by shrimp waste meal.

Feed conversion ratio

There were significant ($p<0.05$) differences found to exist among dietary treatments for FCR. Values obtained in the study (2.69 - 3.23) were well within the normal range (2.5-4.0) for FCR in laying hens (Li *et al.,* 2024). The findings of the present study agree with that of Agunbiade *et al.* (2004), that the inclusion of SWM in poultry diet had no negative effects on feed conversion ratio. FCR is a measure of the efficiency with which feed consumed is converted into animal products, in this case, poultry eggs. Lower values signify higher efficiency, and vice versa. Thus, birds raised on T4 (75%SWM:25%FM) showed the highest efficiency of feed conversion, having the lowest (2.69) value, followed by T2 (25%SWM:75%FM).

Table 5. Effects of shrimp waste meal on the egg quality parameters of laying hens.

Parameters	Treatments					SEM	P-Value	LOS
	1	2	3	4	5			
Haugh Unit	87.61	89.83	90.53	89.21	88..82	0.66	0.695	NS
Yolk Index	0.50	0.50	0.51	0.51	0.51	0.008	0.984	NS
Albumen Index	0.14	0.14	0.15	0.14	0.14	0.002	0.471	NS
Egg Weight	58.71^{a}	56.18^{b}	57.20^{ab}	57.13^{ab}	57.34^{ab}	0.66	0.695	NS

SEM= standard error of means; LOS= level of significant; *= significant at P<0.05; NS = not significant; a,b = means with different superscripts are significant.

Egg quality characteristics of laying hens fed experimental diets of shrimp waste meal

Results of the egg quality indices of laying hens fed shrimp waste meal-based diets are as shown in Table 5.

Haugh unit

No significant (p>0.05) differences were found to exist among dietary groups. As such, Haugh unit was not affected by inclusion of the different levels of SWM. Values obtained in this study ranged between 87.61-90.53. No significant (p>0.05) differences were found to exist among dietary groups. This finding is corroborated by those of Oduguwa *et al*. (2005) and Abun *et al*. (2019) who observed that no significant (p>0.05) relationship exist between SWM and Haugh unit of eggs. Though not significantly (p>0.05) different, it is noteworthy that eggs collected from birds fed T3 had the highest (90.53) Haugh unit, while the average Haugh unit for the control group was the lowest (87.61). Haugh unit is a measure of egg protein quality based on the height of its egg white (Haugh, 1937). Haugh unit ranges found in this study were optimum, considering the ranking as class AA, for eggs with Haugh units greater than 72 (Stable Micro Systems, 2024).

Yolk index

The effects of dietary treatment on yolk index were not significant (p>0.05). Average yolk index of eggs of laying hens on all SWM based diets were similar to that of the control diet, with values ranging from 0.50-0.52 across the dietary treatments. This range reveals that eggs obtained in this study were of excellent quality, as yolk index has indication on the freshness of the egg and values above 0.38 are considered as extra fresh (Nematinia and Mehdizadeh, 2018).

Albumen index

No significant (p>0.05) differences were found among the different treatment groups for albumen index. The range of values (0.14-0.15 mm) obtained in this study was similar to albumen index values (0.13±0.01 reported by Sogunle *et al*. (2017) for chicken eggs. The albumin index indicates the firmness and viscosity of the egg white, which is considered of utmost importance for internal egg quality (Singh *et al*., 2020). From the range of values reported in this study, the inclusion of shrimp waste meal up to 100% as the animal protein source in laying hens' diets has no detrimental effects on albumen index.

Average egg weight

Laying hens on T4 had significantly (p<0.05) higher egg weight than the other treatments. Birds on T2 had the lowest value (56.18 g). However, birds on all the dietary treatments under study, produced large-sized eggs (56.18-58.71g), according to the classification of eggs by Kriel (2024), who revealed that large-sized eggs range between 52 - 69 g. The range of average egg weights obtained in this study reveals that shrimp waste has the potential to support optimum egg weight in a similar manner as fish meal. This result disagreed with that of Oduguwa *et al*. (2005) who suggested the use of shrimp waste up to 4% in laying hens' diets, stating that higher levels of inclusion had detrimental effects, as birds on diets containing up to 100% replacement of fish meal by shrimp waste, produced similar large sized eggs as those on the control diet. It however agreed with the findings of Abun *et al*. (2019) who submitted that the quality of chicken eggs from hens fed SWM was better than that of hens raised on standard rations. Values of egg weight obtained, are directly proportional to the percentage of hen-day egg production, as well as an indication of the efficiency of feed conversion. The favourable results for egg weight obtained in this study agreed with the findings of Abun *et al.* (2019) that shrimp skin contains carotenoids in the form of astaxanthin, which is a provitamin A (β- carotene), used in the formation of the chicken egg yolk. Contrary to the findings of Hamady and Farroh (2020) that egg mass decreased with the intake of chitosan (an amino polysaccharide), Tabata *et al.* (2017) exonerate chitin, with

Table 6. Economics of production of dietary treatments of feeding shrimp waste meal-based diets to laying hens.

Parameter	Treatments					SEM
	1	2	3	4	5	
Cost of feed ₦/kg	588.76	570.76	532.76	524.76	509.56	7.96
Total feed intake (g)	70450.77[e]	65561.72[d]	61930.68[c]	66627.68[b]	67999.68[a]	752.44
Cost of feed/bird/day (₦)	82.30[a]	73.57[b]	67.92[b]	70.70[b]	68.75[b]	1.68
Cost of feed/egg produced (₦)	95.68[a]	86.15[b]	83.90[c]	80.53[d]	86.93[b]	1.37
Cost differential (₦)	0.00[d]	9.53[c]	11.78[b]	15.48[a]	8.75[c]	1.36

the consequent implication of ash in the reduced digestibility of shrimp waste. Hirano *et al*. (1990) showed that birds can digest up to 90 of chitosan and chitin in the stomach due to the chia gene's expression. Egg size is one of the foremost determinants of the acceptability and marketability of poultry eggs, as such shrimp waste has the potential of value addition, to the egg production industry.

Economics of production of laying chickens fed diets containing shrimp waste meal-based diets

The cost of feed per kg obtained in this study was significantly ($p<0.01$) different among dietary groups. The values decreased with increasing levels of SWM, as shown in Table 6. Total feed intake for the twelve weeks showed a significantly ($p<0.01$) higher value (70450.77) in T1(0%SWM:100% FM) than the other dietary groups. A similar trend was revealed in feed intake per bird per day.

The cost of feed per bird per day per treatment decreased as the inclusion level of shrimp waste meals increased across the dietary treatments. This was reflected in the lower cost of SWM based diets as compared to the control. The lower cost persisted even when feed consumption was comparably high in T5 (100%SWM:0%FM).

Significant differences ($p<0.01$) were found to exist in the cost of production of the different diets containing varying levels of shrimp waste meal. A trend of declining cost values (₦82.30, ₦73.57, and ₦67.92), was observed from T1-T3, respectively, except for T4 and T5 with cost values of ₦70.70 and ₦68.75 which was not significantly ($p>0.05$) different from those of T2 and T3. The general trend in cost reduction as levels replacement of fish meal by shrimp waste meal increased, was attributable to the marked reduced cost of shrimp waste meal in comparison with that of fish meal.

A significant ($p<0.01$) decrease was observed in the cost of one unit of egg produced across the dietary treatments. The cost differential also revealed a gradual increase in marginal cost returns as the percentage replacement of fish meal by shrimp waste meal increased. T4 (75%SWM:25%FM) had the highest cost difference of ₦15.48 per egg produced. The lower cost difference of T5 (100%SWM:0%FM) was a result of the increased feed intake, as a result of the pleasant aroma and palatability of the diet, owing to the high SWM content. The standard error of estimate (SEM) of 1.36 - 1.37 of the cost differential and cost per egg produced, lend credence to the comparison of cost for different levels of replacement of fish meal by shrimp waste meal. The results of the economics of production as revealed in this study, prove that SWM is a viable and economical substitute for fish meal, in laying hens' diets at 75% replacement with the accompanying performance credentials earlier discussed.

Conclusion/Recommendation

From this study, it can be concluded that the feed intake of the test animals (layers) of SWM based diets was optimum with greater feed intake tending towards greater levels of SWM inclusion. High efficiency of feed conversion was observed in terms of percentage hen-day egg production, with 75% replacement of fish meal with shrimp waste meal, having the highest efficiency. Egg quality characteristics were maintained in birds fed graded levels of shrimp waste meal. At increasing levels of shrimp waste meal inclusion, the least cost of production was achieved. The study therefore recommends that shrimp waste meal obtained from extractive fishing could be used as a viable animal protein source in laying hen diets. A layer ration containing 75% shrimp waste meal and 25% fish meal supports optimum hen-day production, egg quality characteristics as well as profit maximization. Therefore, 75% replacement of fish meal with shrimp waste meal is recommended.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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