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Shrimp Waste Meal an Alternative Protein Supplement for Replacing Fish Meal in Poultry Diets

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Abstract

The main hurdle in the development of Poultry Industry is the increasing feed cost. Fish meal is the conventional protein supplement used in the poultry diets. The increasing cost of fish meal has led to the use of alternate feed supplements. Shrimp waste meal (SWM) is one such supplement obtained from the processing of shrimp for human consumption. Experiments were carried out to evaluate the shrimp waste meal. The shrimp waste meal was used in poultry diets by replacing the fish meal at different levels. The shrimp waste meal (SWM) reported to have 94.17, 50.5, 8.2, 15.2, 19.1, and 7.0 percent dry matter, crude protein, ether extract, crude fibre, total ash, nitrogen free extract, respectively. The crude protein content of shrimp waste meal ranged from 20.00 - 53.47% as per the reports of many research findings. The calcium and phosphorous content of the SWM was reported as 6.0, and 1.2%, respectively. The percent lysine and methionine were found as 1.66, and 0.88, respectively. Metabolizable energy content of SWM was reported as 1515 kcal/kg diet. The chitin present in the SWM reported to have anti-microbial and immune enhancing activity. The high chitin and calcium contents, could limit the amount of shrimp waste in mono-gastric diets. Chitin has low digestibility when fed to animals. The concentration of E.coli in the caecum was significantly decreased by dietary supplementation of 100 mg/kg of chito-oligosaccharide. Higher serum total protein content was observed when broilers were supplemented with chito-oligosaccharide at 100 mg/kg level. Replacement of fishmeal upto 50% with shrimp waste meal along with supplementation of synthetic lysine and methionine in broiler diets showed significantly ($p < 0.01$) higher liver, gizzard and heart weights (g). The birds also showed higher live weight gain, hot carcass weight and dressing percentage. Up to 50% replacement of fish meal with shrimp waste meal in broiler diets had no effect on mortality rate.

Key Words : Shrimp Waste meal; Chito-oligosaccharide; Broiler diets.

Introduction

The Poultry Industry has emerged as the fastest growing segment of the livestock sector globally due to a number of favorable reasons. Poultry sector, besides providing direct or indirect employment to people, is also a potential tool for ameliorating poverty for many landless and marginal farmers. In addition to contributing to improved human nutrition and food security by being a leading source of high quality protein, poultry/chicken is of economic, social and cultural significance in small societies (FAO, 2010).

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Indian Poultry Industry ranks 3rd in egg production and 5th in broiler production (USDA, 2013). Poultry Industry has however been confronted with the challenges of high cost and scarcity of feed inputs. Feed costs account for nearly 70-80% of the total costs in poultry production. Fishmeal is the only conventional animal protein source for poultry in the country, and poultry is in competition with human and other livestock for dry fish consumption. As a result, the cost of fishmeal is very high and its inclusion in the diet hardly permits profitable poultry farming. The quality of fishmeal is very much variable and availability is uncertain. Fishmeal is often adulterated with other ingredients such as fish bones, sand, sawdust, etc., which adversely affect its nutritive value. Producers sometimes use insecticides for preservation of fishmeal, which may cause toxicity in poultry. Therefore research efforts had been geared towards the use of locally available feedstuffs such as agro-industrial by-products and farm wastes which are less expensive when compared to conventional feed stuffs so that they can be used as a substitute for conventional sources of protein such as fish meal and soya bean meal.

Shrimp waste meal is one of such unconventional protein source that has the potential of being an alternative source of protein in broiler rations, partially or totally replacing conventional protein sources like fish meal. Shrimp waste meal is the dried and milled waste of the shrimp industry which consists of heads, shells and appendages of shrimp (Ingweye et al., 2008). During shrimp processing, the peeling step generates large amount of solid waste. Continuous production of shrimp waste with-out corresponding technology of utilizing the waste has resulted in waste collection, disposal and pollution problem. Shrimp waste can be potentially channeled as a substitute for fish meal in poultry diets.

Shrimp waste is the concentrated product containing proteins with characters of low cost, moisture, deodorized, high digestibility, easy storage that does not require refrigeration and have long shelf life. Shrimp waste contains high CP content and reasonably good balance of essential amino acids (Ngoan et al., 2000). It is particularly rich in lysine which makes it an ideal supplement for cereals (Fanimo et al., 1996). It is palatable and has a pleasant aroma.

Shrimp waste contains 7.87% of water, 26.89% of crude fiber, 24.03% of crude protein, 5.14% of crude fat, 25.60% of ash, 16.69% of calcium and 930 kcal ME/kg (Mahata et al., 2008). Shrimp waste apart from supplying good quality proteins and vitamins A and D, also contains several dietary minerals such as Ca, Fe etc.

Shrimp meal (SM) can be used as a protein source in poultry diets (Fanimo et al., 1996; Rosenfeld et al., 1997; Gernat, 2001; Oduguwa et al., 2004; Khempaka et al.,2006a) or as a source of prebiotic (Khempaka et al., 2011, Zhou et al., 2009) with varying results.

The potentials of shrimp waste meal (SWM) as an alternative protein source in monogastric feeding is not in doubt (Talabi, 1988; Fox et al., 1994). However, the extent of its usefulness and levels of utilization by monogastric livestock is yet to be resolved. To date limited works are carried out in this aspect with variable results.

The present article will review the research work carried by various research workers regarding performance of broilers fed diets containing shrimp waste meal at various levels in terms of body weight gain, feed intake, feed efficiency, digestibility of nutrients, E.coli and Salmonella count of the cecal contents, serological parameters, hematological parameters and carcass traits.

Chemical Composition of Shrimp Waste Meal

Shrimp waste meal is a byproduct from shrimp processing industry and has a high nutritive value (Ngo and le, 2003). Shrimp waste is essentially composed of heads, shells, appendages and tails (Fanimo et al., 2000). The shrimp processing industry has been rapidly growing with significant increase in cultured shrimp production in the South-East Asian region. During shrimp processing the peeling step generates large amount of solid waste, because head and peel represent 40% of the shrimp weight (Gildberg and Stenberg, 2001). The shrimp processing waste generated in India is around 1.25 to 1.50 lakh tons per annum. The major components of the shrimp waste (DM basis) are protein (35-50%), chitin (15-25%), minerals (10-15%) and carotenoids (Ramyadevi et al., 2012).

Shrimp waste is an excellent source of protein (50-60% on DMB), very low in fat and calories. Shrimp waste apart from supplying good quality protein and vit. A & D, it also contains several dietary minerals such as Ca, Fe etc., which are beneficial to animals (Ravichandran et al., 2009). SWM is particularly rich in lysine, which makes it an ideal supplement for cereals (Fanimo et al., 1996).

The chemical composition of shrimp waste meal as reported by various authors is presented in Table

1. CP value of SWM ranged from 20% (Okonkwo et al., 2012) to 50.89% (Rosenfeld et al., 1997), whereas Total ash ranged from 15.64% (Rosenfeld et al., 1997) to 26.73% (Khempaka et al., 2006a), crude fibre ranged from 3.6% (Fanimo et al., 1998) to 29.75% (Khempaka et al., 2006a) and crude fat from 0.94% (Khempaka et al., 2006a) to 10.28% (Khempaka et al., 2011). This variation among studies may be due to the difference in shrimp species (Ngoan et al., 2000; Heu et al., 2003), source of shrimp waste meal (head/shell) (Meyers, 1986) and/or processing method, as these can affect the nutritional values of SWM.

According to NRC (1994) the calcium content of the shrimp waste is 16-50 times more calcium than in fish meal. Mahata et al.,(2008) found the calcium in shrimp waste hydrolysate as 16.35% and phosphorous as 0.83%.The calcium and phosphorous have an antagonistic relationship in the process of absorption in small intestine of the broilers. The high calcium content in broiler diet will reduce the absorption of phosphorous and high phosphorous in diet will lower the absorption of calcium. The calcium and phosphorous deposition will determine the formation of hydroxyapatite for bone compactness during the mineralization process.

Bronner (1987) stated that the contents of the poultry intestine is almost acidic than alkaline. Kheiri and Rahmani (2006) found that Ca might increase the intestinal pH and consequently affect the digestion and absorption of nutrients. High levels of Ca in diet changes the intestinal pH of broiler from acidic to alkaline; this is a possible cause of lower protein digestion and absorption. Scott et al. (1982) also stated that protein plays an important role for broiler growth and protein deficiency will decrease weight gain.

Table 1: Chemical composition (%) of shrimp waste meal as reported by different authors

CP	EE	TA	CF	Ca	P	ME (kcal/kg)	Reference
20.00	7.44	24.50	8.46	NA	NA	NA	Okonkwo et al., 2012
31.58	9.49	19.67	19.82	NA	NA	4023 (GE)	Septinova et al., 2012
36.69	10.28	21.77	19.49	4.92	1.20	1515	Khempaka et al., 2011
48.30	5.75	NA	12.90	3.50	1.00	1870	Aktar et al., 2011
32.50	9.80	26.60	8.70	NA	NA	NA	Ravichandran et al.,2009
24.03	5.14	25.60	26.89	16.69	0.85	938	Mahata et al., 2008
48.30	6.30	17.55	13.30	NA	NA	NA	Ingweye et al., 2008
39.32	0.94	26.73	29.75	6.05	0.97	1,350	Khempaka et al., 2006a
53.47	3.42	16.80	1.18	0.74	0.31	1312	Ojewola and Annah, 2006
40.20	4.80	16.20	10.90	NA	NA	NA	Oduguwa et al., 2004
46.30	9.04	17.04	4.30	7.00	3.03	2500	Fanimo and Oduguwa, 1999
43.71	8.64	17.04	3.60	10.21	0.48	NA	Fanimo et al., 1998
50.89	6.31	15.64	8.92	5.21	1.47	2397	Rosenfeld et al., 1997

Properly collected, preserved and processed good quality SWM with reduced amount of bacterial activity is essential, which otherwise can produce a dicarboxylic reaction turning amino acids from animal protein into biogenic amines, resulting in a toxic effect with the possibility of reducing performance and livability in birds (Dale,1994).

The exo-skeleton of the shrimp is mainly composed of chitin. Subasinghe,(1999) reported that the head, shell and hull of shrimp waste products contained 11, 27 and 24% chitin, respectively. Chitin is a linear polymer of N-acetyl-D-glucosamine unit linked with β (1, 4) glycosidic bonds (Minoru et al., 2002) and chitinase is the enzyme that catalyzes the hydrolysis of chitin to its simple monomer of N-acetyl-D-glucosamine (Park et al., 1997). Chitin physically blocks the access of digestive enzyme to protein and lipid, thus affecting the utilization of these nutrients (Castro et al., 1989). About 10% of the crude protein in whole shrimp meal originates from chitin while up to 50% of the nitrogen in scale meal, originates from chitin (Gohl, 1975).

The major concern with the use of shrimp waste meal is its chitin content which is considered to have low digestibility when fed to animal (Austin et al., 1981). Some species of birds produce chitinase in the proventriculus. In case of the chicken, amounts of chitinase produced are low (Jeuniaux and Cornelius, 1978). Even in species that produce useful levels of chitinase the energy value of chitin is very low, due to poor absorption (Jeuniaux and Cornelius, 1978; Karasov, 1990). Low levels of chitin (0.5%) in broiler diets may improve growth performance.

Fanimo et al. (2000) assessed protein quality of SWM in a balance experiment with rats and results indicated that SWM is inferior to that of fish meal but that supplemental methionine and lysine in SWM diets improved the quality of protein. Ngoan et al. (2000) indicated that the amino acid composition of shrimp waste was fairly balanced, but the low methionine content can limit its value for mono-gastric animals. Other factors such as high chitin and calcium contents, could limit the amount of shrimp waste in mono- gastric diets. Chitin has low digestibility when fed to animals.

Chen et al. (2002) reported that degradation of chitin in SWM may give rise to physiological effects including anti-microbial and immune enhancing activity. Chitin digestibility in broilers has reported to be as low as about 20% (Khempaka et al., 2006 b), although chitinolytic activity occurred in mucosa of the proventriculus in broilers (Koh and Iwamae, 2013).

Mustanur and Katsuki, (2014) reported that in Comparison with hulls, shrimp heads were significantly rich in crude protein (CP) and ether extract (EE) and poor in crude fibre (CF), Total ash (TA) and chitin. Overall, in vitro dry matter (DM) and CP digestibilities were significantly greater in heads than in hulls, which is reasonable because the level of chitin, non-digestible amino polysaccharides, were greater in hulls than heads in all species. Consequently, heads are considered to be more preferable than hulls as a source to generate a good nutritional quality SWM.

Mounica et al., (2019a) evaluated the shrimp waste meal (SWM) and reported percent dry matter, crude protein, ether extract, crude fibre, total ash, nitrogen free extract as 94.17, 50.5, 8.2, 15.2, 19.1, and 7.0, respectively. The calcium and phosphorous content of the SWM was reported as 6.0, and 1.2%, respectively. The percent lysine and methionine were found as 1.66, and 0.88, respectively. Metabolizable energy content of SWM was reported as 1515 kcal/kg diet.

In Vivo Impact of Shrimp Waste Meal on Broiler Performance

Effect of supplementation of shrimp waste meal on body weight gain

Damron et al. (1964) and Raab et al. (1971) incorporated shrimp waste meal at 9.1 and 6.8% in broiler diets and found no statistical difference in performance. Ilian et al. (1985) used shrimp meal, at levels above 10% and found no negative effect regarding broiler productive variables. Islam et al. (1994) reported that chickens receiving the diets containing 14.3% shrimp meal did not show negative effects on body weight gain.

Fanimo et al. (1996) reported non-significant differences regarding body weight gain of broilers both at starter and finisher phase among treatment groups where fish meal contribution to dietary CP of broiler diets was replaced with SWM at 33% level, however significant reduction of body weight gain was noticed at 66 and 100 % level of replacement. Fanimo et al. (1996) suggested that supplementation of shrimp waste meal diets with synthetic methionine and lysine improve the utilization of shrimp waste protein, because the protein quality of shrimp waste meal is inferior to that of fish meal.

Razdan et al., (1997) observed that decreased feed intake and body weight gain when broiler chicks fed with high dietary chitosan (30g/kg) concentration in diets might be induced by the high viscosity and slow motility of the chitosan in the gastrointestinal lumen, stimulating the satiety centre of the brain. Arellano et al. (1997) carried out studies with shrimp meal, by including it in broiler rations at 3, 6 and 9% and found no statistical differences ($P>0.01$) in weight gain per bird.

Okoye et al. (2005) concluded that dietary treatments (0%, 10%, 20% and 30% SWM) had significant effect ($P<0.05$) on body weight gain at the starter phase but not at finisher phase. At the starter phase birds fed 0 % and 10 % SWM diets had statistically comparable weight gain while those fed 20 %, 30 % SWM diets had depressed weight gain at starter phase. At finisher phase, all diets were comparable regarding body weight gain. The decline in performance of birds fed 20 and 30% SWM diets was observed especially at the starter phase. Increased inclusion level of SWM in broiler diets leads to an increase in the total chitin content in the diet resulting in low digestibility of nutrients and absorption in the gastro intestinal tract of broilers. The comparable performance observed at the finisher phase could be as a result of maturity and or age. This is because, as the birds increase in age the gastro intestinal tract and absorption capacity become more efficient in carrying out digestive processes. An indication that older birds were better able to take up chitin than the younger birds.

Ojewola and Annah, (2006) reported that non-significant differences ($P>0.05$) were noticed regarding body weight gain among different dietary treatments with 6 % Danish fish meal, 6 % Cray fish dust meal, 6 % shrimp waste meal, 3% Cray fish dust meal+3% shrimp waste meal, 3 % Danish fish meal + 3 % Cray fish dust meal, 3 % Danish fish meal+ 3 % shrimp waste meal.

Khempaka et al. (2006a) conducted feeding trials with broilers by incorporating SWM at 0%, 4%, 8%, 12% and 16%. There was no significant difference in body weight gains up to 8% inclusion of SWM, but there was significant decrease in body weight gain at 12% and 16% inclusion of SWM in comparison with control and 4% inclusion of SWM. They concluded that decreased body weight gain might have resulted from decreased feed intake and DM digestibility. The SWM used in the study was rich in fiber, ash and poor in CP. It is rich in chitin which might have decreased digestibility and high levels of chitin and or calcium in SWM are possible factors involved in decreased performance.

Ingweye et al. (2008) stated that no significant difference was observed regarding body weight gain in broilers in control (FM replaced with 0% Fish waste meal-FWM) and 25% FWM replaced with SWM but 100% replacement level had least weight gain which did not differ significantly with 50% and 75% replacement levels. The initial slow growth rate with increase in the quantity of SWM in the diet could be inability of birds to handle effectively the highly chitinous diets at tender age.

Mahata et al. (2008) reported that statistical analysis showed significant difference among dietary treatments (0, 4, 8 and 12% SWH) regarding the effects of shrimp waste hydrolysate towards weight gain. Beyond 8% level i.e. birds given diets containing 12% SWH had significantly decreased body weight gain when compared to birds fed other diets.

Iyamu and Uwagboe (2009) conducted a growth trial in broilers. He incorporated shrimp meal at 0, 25, 50, 75 and 100% levels by replacing fish meal and concluded that there was no significant difference between treatments mean for average weight gain. He suggested that shrimp waste meal could replace fish meal protein in diets of broilers.

Khempaka et al. (2011) concluded that inclusion of shrimp waste meal up to 15% did not result in any negative effect on body weight gain. Interestingly the addition of 5% SWM resulted in greater difference in body weight gain when compared to those birds fed control diet, but no significant difference ($P>0.05$) was observed between these two groups fed with 5% and 15% inclusion of SWM.

Aktar et al. (2011) reported that final live weight was highest in diet 4 (Control fish meal -FM diet replaced with 6 % meat waste-MW and 6% shrimp waste-SW), Intermediate in diet 2 (Control FM diet replaced with 12% MW) and diet 3 (Control FM diet replaced with 12 % SW) and lowest in diet 1 (control diet with 12 % FM).

Okonkwo et al. (2012) reported that there were no significant differences regarding body weight gain among treatment means even though the values showed a normal variation, and the values were 290.42 (T1-0% SWM), 328.34 (T2-5% SWM), 274.96 (T3-10% SWM) and 303.75 (T4-15% SWM) when birds are fed with diets containing SWM.

Effect of supplementation of shrimp waste meal on feed intake

Fanimo et al., (1996) reported that non-significant differences were observed regarding feed intake among treatment groups where fish meal contribution to dietary CP of broiler diets was replaced with SWM at 0, 33, 66 and 100 % of graded levels. Arellano et al. (1997) found that inclusion of shrimp meal at 3, 6, 9% levels in diets of broilers produced non-significant effects on feed consumption.

Gernat, (2001) reported a significant ($P<0.01$) increase in feed consumption with both 40 and 80% SWM compared to the 0% treatment. Experimental diets include - five different levels of SWM in the diet replacing 0, 20, 40, 60, or 80% of the SBM. These results might be attributed to the high levels of chitin found in SWM. Because chitin reduces dietary energy, the layers fed diets with higher levels of SWM increased feed consumption to maintain their energy needs.

Oduguwa et al. (2004) concluded that feed consumption values at the starter and finisher phases revealed that birds fed the control diet (FM/SBM) consumed more than those on the other diets (SBM/SWM and FM/SWM) and the difference in the values between treatment groups (diet 2 and diet 3) were non-significant ($P>0.05$).

Hector and Lourdes, (2005) reported non-significant differences regarding feed intake among treatments groups (3%, 6% and 9% SWM). Okoye et al., (2005) concluded that dietary treatments (0%, 10%, 20% and 30% SWM) had significant effect on feed intake. At starter phase significantly highest feed intake was noticed in birds fed control diet and significantly lowest in birds fed diet with 30 % SWM. At finisher phase, feed intake was found to be significantly highest in birds fed diet containing 20 % SWM.

Khempaka et al. (2006a) concluded that there was no significant difference in feed intake up to 8 % inclusion of SWM, but there was significant decrease in feed intake at 12 % and 16 % inclusion of SWM in comparison with control and 4 % inclusion of SWM. With increase in SWM in the diet, Ca level in diet was increased. It was reported that high levels (1.3-1.5 %) of calcium decreased feed intake in chickens (Smith and Taylor, 1961, Watkins et al., 1989), in addition high levels of sodium in SWM has been reported to decrease feed intake (Damron and Kelly, 1987; Balog and Millar, 1989)

Ingweye et al. (2008) stated that no significant difference was observed regarding feed intake among dietary treatment groups. Replacement of fish meal with shrimp waste meal at 0 (T_1), 25 (T_2), 50 (T_3), 75 (T_4) and 100 % levels (T_5) showed that the feed intake ranged from 296.15±36.55 to 328.85±41.21 g/bird, 947.49 ±76.98 to 1048.13±69.79 g/bird and 621.82±71.33 to 688.49±57.08 g/bird for the starter, finisher and combined phases, respectively.

Mahata et al. (2008) reported that statistical analysis showed non-significant difference with regard to feed consumption among treatment groups (0, 4, 8 and 12%). Iyamu and Uwagboe (2009) carried out studies in broilers where shrimp meal was incorporated at 0, 25, 50, 75, and 100% of graded levels by replacing fish meal in the experimental diets. No statistical difference was found ($P>0.05$) regarding feed consumption among treatment groups.

Aktar et al. (2011) reported that feed consumption of broilers at 28 days of age was similar in all experimental diets ($P>0.05$). At 42, 56 days of age highest feed intake was observed in broilers receiving diet 1 (control diet with 12 % Fish meal) and lowest on diet 4 (Fish meal of the control diet replaced with 6% Meat waste and 6% Shrimp waste) and intermediate in diet 2 (Fish meal of the control diet replaced with 12 % Meat waste) and diet 3 (Fish meal of the control diet replaced with 12 % Shrimp waste).

Khempaka et al. (2011) reported non-significant differences with regard to feed intake among treatment groups (control, 5%, 10%, 15%, 20 % Shrimp waste meal diets). Okonkwo et al. (2012) showed that non-significant differences were observed regarding feed intake among treatment means in spite of the variation in values and the feed intake (g) was 1614.57 (T_1-0% SWM), 1549.00 (T_2-5% SWM), 1525.71 (T_3-10% SWM) and 1541.29 (T_4-15% SWM).

Effect of supplementation of shrimp waste meal on feed conversion ratio (FCR)

Fanimo et al. (1996) reported non-significant differences with regard to FCR of broilers at finisher phase among treatment groups where fish meal contribution to dietary CP of broiler diets was replaced with SWM at 33% and 66% level, however significant difference (poor efficiency) was noticed at 100% level of replacement.

Arellano et al. (1997) conducted a feeding trial in broilers and he reported that the feed efficiency was poorer for the diets containing shrimp meal at 40% and 80% level. The feed efficiency was poorer because of the increase in feed consumption in those dietary treatments.

Experimental reports of Oduguwa et al., (2004) revealed that birds fed with control diet (FM/SB) had best FCR than diet 2 (SBM/SWM) and least with diet 3 (FM/SWM) both during starter and finisher phases. Hector and Lourdes, (2005) reported that FCR was similar for all treatments (control, 3%, 6% and 9% SWM) at starter phase however at finisher phase birds fed control diet (2.44) and birds fed 3% SWM (2.71) had significantly lower FCR than those fed 9% SWM (4.50), while FCR of birds fed 6% SWM was comparable with other treatments (control, 3% and 9 %).

Okoye et al., (2005) concluded that dietary treatments at 0%, 10%, 20% and 30% SWM had significant effect on feed to gain ratio at the starter phase but not at finisher phase. At the starter phase birds fed with 0% and 10% SWM diets had statistically comparable feed to gain ratio while those fed 20%, 30% SWM diets had significantly ($P<0.05$) higher feed to gain ratio. At finisher phase, all diets were comparable regarding feed to gain ratio.

Ojewola and Annah, (2006) reported non-significant differences ($P>0.05$) regarding feed conversion ratio among different dietary treatments (6% Danish fish meal; 6% cray fish dust meal; 6% shrimp waste meal; 3% Cray fish dust meal + 3% shrimp waste meal; 3% Danish fish meal + 3% Cray fish dust meal; 3% Danish fish meal + 3% Shrimp waste meal).

Khempaka et al., (2006a) concluded that there was no significant difference in feed efficiency up to 8% inclusion of SWM, but there was significant ($P<0.05$) decrease in feed efficiency at 12% and 16% inclusion of SWM in comparison with control and 4 % inclusion of SWM.

Ingweye et al. (2008) reported that FCR was best at 0% level of replacement and higher values were recorded for 100% replacement level which did not differ significantly (P>0.05) with 50 and 75% replacement level and thus concluded that 25% level of replacement of FWM with SWM was optimum for broiler performance. The feed conversion ratios were best (P<0.05) at the 0% replacement level for all the phases i.e., 1.45±0.12, 1.90±0.13 and 1.67±0.12 for the starter, finisher and combined phases respectively. These were not different (P>0.05) from the control in all the phases. The worst values (P<0.05) were 3.50±0.22, 3.42±0.25 and 3.46±0.31 recorded for the starter, finisher and combined phases respectively, at 100% replacement level. Feed conversion ratio was inversely related to the feed intake. As the level of shrimp waste in the diet increased, feed conversion ratio increased. This could be as a reflection of increasing feed intake and decreasing weight gain.

Mahata et al. (2008) reported that the statistical analysis showed significant difference among dietary treatments (0, 4, 8 and 12% Shrimp waste hydrolysate) regarding FCR. The FCR beyond 8% level of inclusion i.e birds fed diet with 12 % SWH had significantly higher FCR when compared to birds fed other experimental diets. Khempaka et al. (2011) reported that FCR did not change significantly when SWM was at or below 15%. Interestingly the addition of 5% SWM resulted in greater difference in FCR (1.88) when compared to those birds fed control diet (1.95), but no significant difference (P>0.05) was observed between these two groups (control and 5% SWM).

Iyamu and Uwagboe (2009) reported that there was no statistical difference (P>0.05) among dietary treatments (0, 25, 50, 75, 100%) regarding FCR. Aktar et al. (2011) reported that feed conversion of broilers at 28 days of age did not differ significantly (P>0.05) among experimental diets. But at 56 days of age highest feed conversion was observed with diet 4 (FM of Control diet replaced with 6% MW and 6% SW) and lowest with diet 1 (control diet with 12% FM) (P<0.01).

Okonkwo et al. (2012) showed that feed conversion ratio did not differ significantly among dietary treatments (T_1-0% SWM), (T_2-5% SWM), (T_3-10% SWM) and (T_4-15% SWM) but numerically lower values were observed in SWM supplemented groups when compared to control.

Effect of supplementation of shrimp waste meal on nutrient digestibility

Gohl, 1975 reported that about 10% of the crude protein in whole shrimp meal originates from chitin while up to 50% of the nitrogen in scale meal originates from chitin which is nearly indigestible.

The enhanced ileal digestibility of nutrients in the broilers fed chitin oligosaccharide containing diets might be due to reduced number of pathogenic bacteria like Escherichia coli, Salmonella typhimurium (Choi et al., 1994; LeMieux et al., 2003; Wang et al., 2003., Boyle et al., 2007; McNulty et al., 2007) and increase in the number of the beneficial bacteria like Lactobacilli (Oli et al., 1998) in the intestine. Such changes in the intestinal bacterial population resulted in a decrease in the incidence of diarrhoea (Oli et al., 1998) and increase in immune function (Gibson and Roberfroid, 1995; Patterson and Burkholder, 2003).

The chito-oligosaccharides may stimulate the secretion of digestive enzymes from the stomach, pancreas and intestinal mucosa (Hou and Gao, 2001). This effect is expected to reduce local inflammation in the intestinal mucosa, facilitate the breakdown of complex molecules into simpler ones and enhance the integrity of enterocytes, thereby promoting the digestion and absorption of nutrients (Wu, 1998). Through an increase in the digestion and absorption of nutrients, dietary supplementation with COS reduces the excretion of fecal nitrogen and phosphorus from animals, thereby minimizing the major sources of environmental pollution.

Dietary supplementation of 100 mg/kg of COS to broilers was as effective as well-documented antibiotics (6 mg/kg of flavomycin) in enhancing the ileal digestibility of nutrients and average daily gain, compared with the broilers fed the basal diet. Thus, compared with feeding an antibiotic, dietary COS supplementation to poultry and other livestock species offers three unique advantages: 1) preventing drug resistance in animals and humans; 2) improving the health of the small intestine; and 3) increasing the ileal digestibility of dietary phosphorus (Huang et al., 2005). Chitin physically blocks the access of digestive enzymes to lipids and protein thus effecting the utilization of these nutrients (Castro et al., 1989, Karasov, 1990).

Hector and Lourdes, (2005) reported that body weights of broilers decreased significantly as percentage of shrimp meal increased beyond 6 % in the diet. Khempaka et al. (2006a) concluded that there were no significant differences regarding DM digestibility and nitrogen retention up to 8 % inclusion of SWM, but there was significant reduction at 12% and 16% inclusion of SWM in comparison with control and 4% inclusion of SWM.

Ojewola and Annah, (2006) reported that non-significant differences were observed regarding fat, ash, crude fiber digestibility and nitrogen retention among treatment groups (6% Danish fish meal; 6% Cray fish dust meal; 6% shrimp waste meal; 3% Cray fish dust meal + 3% Shrimp waste meal; 3% Danish fish meal + 3% Cray fish dust meal; 3% Danish fish meal + 3% Shrimp waste meal).

Mahata et al. (2008) reported that statistical analysis showed significant difference among dietary treatments regarding effects of shrimp waste hydrolysate toward nitrogen retention beyond 8% level of inclusion i.e birds fed diet with 12% SWH had significantly lower nitrogen retention values when compared to birds fed other diets. Khempaka et al. (2011) reported that DM, OM and Ash digestibility values and nitrogen retention did not change significantly when SWM was at or below 15%.

Khambualai et al. (2008 and 2009) reported that supplementation of low dietary chitosan (0.6g/kg) concentration until 7 weeks of age in marshal chunky broiler chicks had increased feed intake and body weight gain due to better absorption of nutrients.

Effect of supplementation of Shrimp waste meal on microbial count

The use of shrimp waste meal as a protein source in poultry diets have a beneficial effect, it can potentially alter the microbial ecology of the intestine. Acidic digestive fluid in the proventriculus and gizzard may degrade the shrimp shell to release chitin. In the neutral pH of the small intestine, chitin would gradually precipitate and move into the large intestine (mainly the caeca), where microbes may release enzymes to hydrolyze chitin.

The degradation products of chitin can inhibit the growth of harmful bacteria (Chen et al., 2002) and enhance the growth of Bacteroides spp. in the ceca of rats (Chen and Chen, 1999). It is well known that the microbial community and its activity play important role in the intestinal, physiological, immunological and protective functions of the poultry intestinal tract and can be influenced by diet composition.

Salmonella spp., pathogenic E. coli, considered to be food borne pathogens and they are commonly found in the gastrointestinal tract of poultry. Izat et al. (1991) reported that poultry products are frequently contaminated with various serotypes of Salmonella and with E. coli strain O157:H7. Salmonellosis in humans is most frequently associated with the consumption of contaminated fresh and processed poultry products (Lynch et al., 2006; Foley et al., 2011). According to Foley et al. (2011) Salmonella Typhimurium continues to be among the most common serovars isolated from poultry and a common cause of human salmonellosis. Furthermore, public concern associated with antibacterial strains is challenging the poultry industry to find alternative means of control and consequently, continuous studies on alternative methods to control food borne pathogens are necessary (Boyle et al., 2007; McNulty et al., 2007 and Menconi et al., 2014). Feeding SWM has shown to enhance the growth of Lactobacillus and to inhibit the growth of E. coli and Salmonella in the intestine.

Khempaka et al. (2006b) reported that approximately 20% of chitin can be digested in the gastrointestinal tract of broilers. Chen et al. (2002) reported that degradation of chitin in SWM may give rise to physiological effects including anti-microbial and immune enhancing activity.

Li et al. (2007) reported that the concentration of E.coli in the caecum was significantly decreased by dietary supplementation of 100 mg/kg of chito-oligosaccharide in comparison with the control birds. Khempaka et al. (2011) reported that feeding broilers with SWM resulted in increased population of lacto bacillus and decreased intestinal Escherichia coli and cecal Salmonella. Menconi et al. (2014) reported that in vivo reduction in cecal Salmonella Typhimurium (ST) may decrease the overall pathogen load in birds, making them less likely to spread the infection further. They reported that the addition of 0.2% chitosan in broiler diet proved to be an effective alternative tool to reduce colonization of ST in broiler chickens and significantly reduced ST counts in crop and cecal content leading to reduced carcass ST contamination as well as decreasing the amount of ST shed to the environment.

Effect of supplementation of shrimp waste meal on serum constituents (Protein, Albumin, Globulin, Cholesterol, Glucose)

Kobayashi and Itoh, (1991) reported that dietary chitosan inhibited the increases in plasma triglyceride concentration and abdominal fat weight in laying type chicks fed high-fat diets.

Olayemi, (2001) reported that non-significant differences were observed regarding serum metabolites among dietary treatments T_1 (soya bean & fish meal), T_2 (FM was replaced with SWM), T_3 (SBM was replaced with SWM). Li et al., (2007) reported that higher serum total protein content was observed when broilers were supplemented with chito-oligosaccharide at 100 mg/kg level than other treatment birds.

Zhou et al. (2009) reported that chito oligosaccharide supplementation had no effect on the total protein in treatment and control groups. Abiodun Adeyeye et al. (2014) reported that the levels of serum cholesterol increased as the level of SWM substitution increased in turkey poults.

Effect of supplementation of shrimp waste meal on hematological parameters

Meng et al. (2010) reported an increase in the concentration of WBC when laying hens were fed chito-oligosaccharides at 0.4 % of diet. Chen et al. (2002) concluded that 5g/kg of chito-oligosaccharides supplementation added in the diet did not affect the concentration of WBC, RBC and lymphocyte.

Zhou et al. (2009) reported that the RBC counts were 18.2% greater in birds fed chito-oligosaccharides at 0.4 % of diet than in birds in the control group. However, chito-oligosaccharide supplementation had no effect on the white blood cells and lymphocytes.

Mounica et al. (2019b) carried out an experiment to assess the effect of feeding Shrimp waste meal as a replacement for fish meal on serological, hematological parameters and carcass traits in broilers. The growth trial was conducted for 42 days using 375 commercial day old chicks which were distributed randomly into five treatments groups with three replicates of twenty five birds each. In pre-starter diet, fish meal contribution to the dietary crude protein was replaced with shrimp waste meal at 0% (T1), 20% (T2), 30% (T3), T2 + synthetic lysine and methionine (T4), T3 + synthetic lysine and methionine (T5). In starter and finisher diets the shrimp waste meal protein was added up to the 0% (T1), 50% (T2), 100% (T3), 50% + synthetic lysine and methionine (T4), 100% + synthetic lysine and methionine (T5). In pre-starter and starter phases no significant differences were noticed regarding levels of serum total protein (g/dl), albumin (g/dl), globulin (g/dl), glucose (mg/dl) and cholesterol (mg/dl) among treatments. Similarly, in finisher phase there were no significant difference in levels of serum total protein (g/dl), albumin (g/dl) and glucose (mg/dl) among treatments, except the serum cholesterol levels (mg/dl) and globulin levels (g/dl) were found significantly ($p < 0.01$) higher in birds fed T1 diet than birds fed other diets (T2, T3, T4 and T5). Non significant differences were noticed among treatment groups regarding RBC count during the three phases of the study.

Effect of supplementation of shrimp waste meal on broiler carcass traits

Fanimo et al. (1998) reported increase in the liver weight and decrease in plucked weight with increase in shrimp waste meal in the diet. However, no significant difference was reported regarding dressing percentage among treatment groups (dietary CP contributed by FM was replaced with SWM at 0, 33, 66 and 100 % graded levels).

Olayemi, (2001) reported non-significant differences regarding gizzard, spleen, kidney and lung weight but heart & liver weight varied significantly among treatment groups (T_1-soya bean & fish meal, T_2-FM was replaced with SWM, T_3-SBM was replaced with SWM). Cunha et al. (2003) reported that no significant differences were observed regarding breast, thigh and drumstick yield of broilers fed 0, 3, 6, 9 and 12 % Shrimp waste meal.

Agunbiade et al. (2004) reported non-significant differences among treatment groups for liver, heart and gizzard weight in broilers fed cassava products diets supplemented with Shrimp waste meal. Hector and Lourdes, (2005) reported that final live body weight and plucked carcass weight were similar for control, 3% and 6% SWM treatments but significantly higher than 9% fed group. Dressed carcass weight of control and 3% SWM fed groups was significantly higher than 6% and 9% SWM diets.

Mahata et al. (2008) reported that statistical analysis showed non-significant differences among dietary treatments (0, 4, 8 and 12% SWH) with regard to carcass percentage. The average percent of digestive organs: liver, proventriculus and gizzard were not significantly affected by shrimp waste supplementation.

Aktar et al. (2011) reported that dressed yield, total meat and drumstick meat were highest ($P<0.01$) on diet 1 (control diet with 12 % FM) and diet 4 (FM of control diet replaced with 6% MW and 6% SW) and intermediate in diet 2 (FM of control diet replaced with 12% MW) and lowest in diet 3 (FM of control diet replaced with 12% SW) and other meat yield characteristics were not influenced by diet ($P>0.05$).

Okonkwo et al. (2012) reported non-significant ($P>0.05$) differences among treatment groups (T_1- 0% SWM, T_2 -5% SWM, T_3-10% SWM and T_4-15% SWM) for plucked weight, dressed weight, eviscerated weight, neck, wing, thigh/drumstick, breast, gizzard, liver and heart weights.

Mounica et al. (2019b) reported that replacement of fishmeal upto 50% with shrimp waste meal along with supplementation of synthetic lysine and methionine in broiler diets showed significantly ($p < 0.01$) higher liver, gizzard and heart weights (g). The birds also showed higher live weight gain, hot carcass weight and dressing percentage.

Effect of supplementation of shrimp waste meal on mortality

Jarquin et al. (1972) found higher mortality in birds fed on diet where shrimp by-product replaced fish meal of control diet. Islam et al. (1994) reported that survivability was similar in control fish meal diet and test diets in which 50% dietary fish meal was replaced with shrimp waste. However, survivability was reduced with diet in which 75% dietary fish meal was replaced by shrimp waste.

Fanimo et al. (1998) reported that mortality increased with level of SWM in the diet at the starter phase. This may be due to the inability of the chicks at this early age to cope up with the chitin level in SWM. Cases of leg problems were observed during the early stage of the birds but they later overcame it. These observed leg problems may be due to the high ash or mineral content (especially Ca:P ratio) of the SWM which may lead to mineral imbalance. Calcium carbonate is responsible for the scleratization of the exoskeleton and represents most of the mineral matter. Because of its high mineral level, SWM is usually used in combination with other protein supplements (Meyer and Rutledge, 1971).

Gernat, (2001) reported non-significant differences among treatment groups with regard to mortality. Mortalities for all treatments (five different levels of SM in the diet replacing 0, 20, 40, 60, or 80% of the SBM) were less than 1%. Aktar et al. (2011) reported that survivability was not affected by different dietary treatments (control diet with 12% Fish meal, FM of control diet replaced with 12% meat waste, FM of control diet replaced with 12% Shrimp waste, FM of control diet replaced with 6% meat waste and 6% shrimp waste).

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