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Short Communication

Inclusion of shrimp waste meal in diet of free-range chickens

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Abstract

Shrimp waste meal (SWM) is a by-product from the processing of shrimp for human consumption. The value of SMW in feeding poultry is not well documented. The objective of this study was to determine the energy value and optimal inclusion level of SWM in the diet of growing chickens. A total of 180 one-day-old broilers were randomly assigned to five treatments with 0, 50, 100, 150 and 200 g/kg of SWM included in their diet. There were six replicates of six birds for each treatment. Dry matter intake (DMI) was not affected by the level of SWM that was fed. Retained dry matter varied from 72.39% in the diet that did not contain SWM to 66.97% in the diet with 200 g/kg of SWM. Nitrogen retention (NR) ranged from 54.70% to 70.10%; N ingested was between 18.71% and 24.03%. Energy intake ranged from 73.57% to 69.33% for the control and the diet with 200 g/kg of SWM, respectively. NR improved with increasing SWM inclusion levels. The apparent metabolizable energy (AME) and corrected apparent energy metabolizable (AMEn) ranged from 2928 to 2527 kcal/kg and 2774 to 2329 kcal/kg, respectively, relative to the control and 200 g/kg SWM diets. The energy consumption, in kcal/kg, of SWM consumed was AME = 2332-6.971 x SWM and AMEn = 2113-8.128 x SWM. High levels of SWM reduce the dry matter metabolization coefficient and metabolizable energy values in broilers during the growing phase, so it is recommended that up to 100 g/kg should be included, which would provide an AMEn of 1300.2 kcal/kg for free-range chickens in dry matter.

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Currently, there has been a significant increase in the desire of people for food that is produced in a way that is environmentally sustainable. Animal welfare has also become a matter of concern for consumers. The broiler chicken industry has responded with a new production model that uses a semi-confined system. One of the challenges of this system is to obtain adequate feed efficiency while keeping production costs low. Diets based on the traditional ingredients of corn and soybean meal are costly, so using alternative inputs could be a viable strategy.

Shrimp waste meal is a by-product of shrimp farming. After processing the whole shrimp (*Litopenaes vannamei*), approximately 44% of the biomass is waste, which is composed of 65% head (cephalothorax) and 35% shell (exoskeleton) (Genart, 2001). However, the usefulness of SWM in diets may be related to the concentrations of the head and shell (Brito *et al.*, 2020). As a dietary ingredient, SWM can be an important source of protein and minerals (Trung & Phuong, 2012). Shrimp waste meal has 61.2% organic matter, 30.4% crude protein, 38.8% ash, and about 9980 kcal metabolizable energy (ME)/kg (Brito *et al.*, 2020). However, its use as a feedstuff has been understudied.

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In addition to its potential value as a feedstuff, the use of SWM in animal diets reduces the need to dispose of this by-product. Thus, the environmental impact of shrimp farming can be reduced. Furthermore, this by-product can be obtained from fishing ports in coastal regions throughout the year and at low cost (Fernandes *et al.*, 2013).

The existence of an optimal level of SMW in the diet for broiler chickens was hypothesized in this study. This optimal level was determined through assessment of ER and NR by broilers that were fed increasing levels of SMW.

All experimental procedures were approved by the Ethics Commission on the Use of Animals (approval no 09/2013). The shrimp residue meal was obtained at a local fishery warehouse in the coastal region of the State of Sergipe, Brazil. It was composed by 76% heads (cephalothorax) and 24% carapace (exoskeleton). The fresh by-product residue was placed on an aluminium platform, covered with 6 × 6 mm plastic mesh, avoiding contact with insects and animals, and dried in the sun for three consecutive days with a thermo-hygrometer installed at a height of 60 cm. After drying, the shrimp waste was milled to obtain 1-mm particles and stored for later use. The crude protein (CP), dry matter (DM), ether extract (EE), ash, and mineral contents of the SWM were determined following AOAC (2012) methods. An adiabatic calorimeter (C-200, IKA Works, Inc., Wilmington, North Carolina, USA) was used to determine gross energy using benzoic acid for calibration. The amino acid composition was determined by Evonik Industries AG (Essen, Germany).

The birds were randomly assigned to one of five treatments with six replicates of each treatment consisting of six birds. The treatments consisted of a basal diet with no SWM (control) (Table 1), and four experimental diets with the addition of 50, 100, 150. and 200 g/kg of SWM, respectively. The basal diet was formulated to meet the nutritional requirements of broilers (Rostagno *et al.*, 2011). The initial diet (1 to 28 days old) was formulated with corn and soybean meal, and contained 220 g/kg CP, 2950 kcal ME/kg; 9.4 g/kg calcium (Ca); 4.2 g/kg potassium (P); and 12 g/kg digestible lysine.

The digestion trial was conducted with 180 male broilers with an average weight of 803 g at 29 days old. From 1 to 28 days old, the birds had been housed in a shed equipped with pendulum feeders and nipple drinkers. On day 29 the birds were moved to metabolic cages (0.60 × 0.50 × 0.40 m) equipped with feeders and drinking fountains. Water and feed were supplied ad libitum throughout the period. The first seven days were for adaptation to diets and metabolic cages, and the excreta was collected over the remaining five days. The excreta were collected twice each day in plastic-coated trays located below the cage floor, put in plastic bags, and stored in a -20 °C freezer until laboratory analysis.

At the end of the period, all excreta samples of the replicates were thawed and homogenized, and 300 g aliquots were removed for pre-drying in a forced-air circulation oven at 55 °C for 72 hours. The samples were then milled in a 1-mm sieve-type mill and sent to the laboratory for DM, CP and EE analysis following AOAC (2012) methods. Similar to the determination of gross energy (GE) for SMW, the adiabatic calorimeter was used to determine GE of both the excreta and diet samples. Based on the laboratory analyses results, ME, DM, and N metabolizable coefficients were calculated using equations proposed by Sakomura and Rostagno (2016). The AME and AMEn values were also corrected for the dietary N level (Sakomura & Rostagno, 2016). The data were analysed with analysis of variance using the GLM procedure of SAS (SAS Institute, Inc., Cary, North Carolina, USA). The treatment averages were compared with linear and quadratic orthogonal polynomial contrasts. Linear regression analysis was used to establish the relationship between AME and AMEn and the level of SWM replacement. Differences detected at the 5% level of probability were considered significant.

Relative to the fresh material, the SWM yield was 23% after drying and processing. The nutritional values of SWM are shown in Table 2. The CP content of the SMW in this study was lower than the 36.7% and 39.4% CP content of shrimp head meal found by Khempaka *et al.* (2006) and Fanimo *et al.* (2004), respectively. Several factors, including the species of shrimp, ratio of heads to carapace, and processing method may have an effect on the nutritional composition of SMW (Mizani *et al.*, 2005).

In this study, the minerals collectively comprised 411 g/kg of SWM, with calcium and phosphorus being the highest percentage, in a 5.3: 1 ratio. This value was higher than was reported by Khempaka *et al.* (2011) in residues of cultured shrimp meal *(Litopenaeus vannamei).* This factor must be considered by nutritionists when using this food, since an imbalance between these minerals could compromise animal metabolism. Crustacean shells have between 30% and 50% of calcium-based compounds, such as carbonates and phosphates, which may limit their use in broiler diets (Suryawanshi *et al*., 2019). Calcium intake above requirements results in decreased plasma parathyroid hormone concentration through a negative feedback mechanism that would affect the absorption of Ca and P (Proszkowiec-Weglarz & Angel, 2013). The calcium content of SMW in the present study was greater than the 10.03% of mineral content in shrimp cephalothorax meal observed by Fernandes *et al*. (2013). In addition, these authors observed a phosphorus content that was slightly less than was found in this work. An imbalance in the ratio of Ca to P

Table 1 Ingredients and nutritional composition of basal diet for the broiler chickens, as-fed basis

Ingredients	Composition (g/kg)
Corn	655.30
Soybean meal 45% crude protein	302.00
Soybean oil	12.58
Dicalcium phosphate	12.25
Limestone	9.27
Sodium chloride	4.31
DL-methionine (99% purity)	1.81
L-Lysine HCL (78% purity)	0.99
Vitamin supplement[1]	1.00
Mineral supplement[2]	0.50
Metabolizable energy, kcal/kg	3000
Analysis, g/kg	
Crude protein	185.0
Fat	41.4
Calcium	73.9
Available phosphorus	55.4
Sodium	19.0
Standardized ileal digestible lysine	97.0
Standardized ileal digestible methionine + cysteine	69.8
Standardized ileal digestible threonine	63.3
Standardized ileal digestible tryptophan	20.1
Electrolyte balance (mEq/kg)[3]	253.6

[1]Per kg of diet: vitamin A: 7000 UI, vitamin D_3: 2500 UI, vitamin E: 18 UI, vitamin K_3: 1 mg, vitamin B_1: 1.5 mg, vitamin B_2: 5.5 mg, vitamin B_6: 1.6 mg, vitamin B_{12}: 12 mcg, pantothenic acid: 10 mg, biotin: 0.05 mg, folic acid: 0.9 mg, nicotinic acid: 32.5 mg
[2]Per kg of diet: iron: 30 mg, manganese: 60 mg, zinc: 50 mg, iodine: 2.5 mg, selenium: 0.25 mg
[3]Mongin, 1981

Table 2 Chemical and amino acid composition of shrimp waste meal, as-fed basis

Nutrients		Minerals	%	Essential amino acids	%[1]	Non-essential amino acids	%[1]
Dry matter, %	89.00	Calcium	12.22	Phenylalanine	2.29 (7.01)	Glutamic acid	3.65 (11.17)
Crude protein, %	32.60	Phosphorus	2.31	Leucine	1.93 (5.91)	Aspartic acid	2.66 (8.15)
Ether extract, %	3.90	Sodium	1.33	Lysine	1.67 (5.10)	Glycine	1.70 (5.22)
Gross energy, kcal/kg	9980	Iron	14.90	Valine	1.51 (4.61)	Alanine	1.58 (4.83)
Ash, %	41.10	Zinc	5.70	Arginine	1.43 (4.39)	Proline	1.17 (3.57)
		Copper	3.20	Isoleucine	1.26 (3.86)	Serine	1.07 (3.27)
		Manganese	1.41	Threonine	1.08 (3.30)	Cysteine	0.31 (0.94)
		Cobalt	0.93	Methionine	0.54 (1.65)		
				Histidine	0.52 (1.59)		

[1]Parenthetical values indicate contribution of the amino acids to crude protein

could compromise the energy metabolism in birds, resulting in inefficient energy use (Adedokun & Adeola, 2013). Tancharoenrat and Ravindran (2014) demonstrated that when mineral levels increased, the digestibility of both fat and protein were decreased. The content of trace elements of SWM, such as zinc and copper, has been shown to meet the nutritional requirements of birds (Rostagno *et al*., 2011), and may therefore be beneficial to intestinal development and animal growth.

No differences were observed in DMI between the SWM inclusion levels (P >0.05). However, digestibility decreased (P <0.01) with an increased level of SWM in the diet (Table 3). There was no significant difference (P >0.05) in the digestibility of the diet until the level of SMW reached 150 g/kg. Increasing the level of SWM in the diet also resulted in decreased energy retention by the birds (P <0.001). Because SWM is rich in CP, the ingested N increased with the level of its inclusion in the diet. However, NR decreased with increased N intake. When the intake of nitrogen is equal to excretion, the animal is in nitrogen balance (McDonald, 1993). However, if the intake exceeds excretion, the animal will be in positive nitrogen balance, as occurred in this study. Khempaka *et al*. (2006) observed similar results in DM digestibility and NR in broilers with the inclusion of up to 80 g/kg of SWM (*Penaeus monodon* shrimp exoskeleton).

Table 3 Dry matter, nitrogen, and energy utilization of free-range chickens fed experimental diets containing 0, 50, 100, 150, and 200 g/kg of shrimp waste meal

Variables	Level of shrimp meal waste included in diet, g/kg					SE	*P*-value[1]	
	0	50	100	150	200		Linear	Quadratic
DMI, g	102.38	103.64	101.24	102.17	101.69	0.52	0.4538	0.1778
DMR, %	72.39	71.17	72.23	69.25	66.97	0.42	<0.0001	0.0004
N ingested mg/g	18.71	18.69	25.77	23.55	24.03	0.57	<0.0001	<0.0001
NR, %	54.70	54.61	75.32	68.79	70.10	1.66	<0.0001	<0.0001
ER, %	73.57	72.70	72.88	71.67	69.33	0.32	<0.0001	0.0069
AME, kcal/kg	2928	2882	2779	2695	2527	27.25	<0.0001	0.0005
AEMn, kcal/kg DMI	2774	2729	2567	2501	2329	30.43	<0.0001	0.0076

[1]Linear and quadratic orthogonal polynomial contrasts
DMI: dry matter intake, DMI%: dry matter retained, N ingested: nitrogen ingested mg/g DMI, NR: nitrogen retained, ER: energy retained, AME: apparent metabolizable energy, AMEn: nitrogen-corrected apparent metabolizable energy

The AME and AMEn of the experimental diets were also reduced as SWM was added (Table 3). Although the diet with 50 g/kg SWM had similar AMEn to the reference diet, the inclusion of 100 g/kg of SWM reduced AMEn concentration by more than 200 kcal. Thus, both AME and AMEn, per kg DM and per kg of feed, were reduced when they were regressed on the level of SWM inclusion (Table 4). When the SWM inclusion level increased from 50 to 200 g/kg, the AME decreased from 1983.45 kcal/kg to 937.8 kcal/kg and AMEn decreased from 1706.6 kcal/kg to 487.4 kcal/kg. Thus, 100 g/kg of shrimp waste meal was judged to be the optimal level of inclusion in terms of its nutritional composition (Ojewola & Annah, 2006) and the age of the birds (Okonkwo *et al.*, 2012).

In conclusion, it was deemed feasible to use SWM as a dietary supplement to provide nutrients for free-range broilers. However, high levels of SWM reduced DM digestibility and ME values for growing broiler chickens. The maximum recommended inclusion level is 100 g/kg of SWM, which would provide chickens with an AMEn of 1300.2 kcal/kg of dry matter.

Table 4 Regression of apparent metabolizable energy and nitrogen-corrected apparent metabolizable energy on level of shrimp waste meal included in the diet for broiler chickens and predicted values for the 100 g/kg level of inclusion

Regression equation	R^2	SE of Intercept	SE of slope	Predicted value at 100 g/kg
Dry matter basis				
AME = 2332 – 6.971 x SWM	0.69	134.856	0.985	1634.9
AMEn = 2113 – 8.128 x SWM	0.70	154.038	1.125	1300.2
As-feed basis				
AME = 2075 – 6.203 x SWM	0.69	120.016	0.876	1454.7
AMEn = 1880 – 7.323 x SWM	0.70	137.121	1.001	1147.7

AME: apparent metabolizable energy (kcal/kg), AMEn: nitrogen-corrected apparent metabolizable energy (kcal/kg), SWM: shrimp waste meal

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Authors' Contributions

MASS collected the data for this study, JMDSV, APDV conducted the statistical analyses, GRL collaborated in interpretation of the results, CMS, COB wrote the initial draft of this manuscript; COB, VRJ, GMOJ developed the original hypotheses and designed the experiments, AC collaborated in interpreting the results, and finalized the manuscript. All authors have read and approved the finalized manuscript.

Conflict of Interest Declaration

The authors declare no conflict of interest.

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