






Feather and blood meal at different processing degrees in broiler pre-starter and starter diets

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ABSTRACT - The objective of this study was to evaluate the inclusion of feather and blood meal (FBM) in broiler pre-starter and starter diets according to the processing method used. Performance, digestibility, and intestinal morphometry of broilers fed diets containing FBM were evaluated in two experiments, in the pre-starter (1-7 d) and starter (8-21 d) phases in a randomized block design with four treatments and five replicates of 12 birds, totaling 20 experimental units per trial. The criteria used for block formation was the battery floor. The meal was processed under different degrees of hydrolysis pressure (2.0 kgf/cm² for 40 min; 2.5 kgf/cm² for 30 min; and 3.0 kgf/cm² for 20 min) and added at 9% to the pre-starter (Experiment I) and starter (Experiment II) diets. In each experiment, 480 male Cobb 500[®] chicks were allocated to batteries. The following variables were measured: live weight, weight gain, feed intake, feed conversion ratio, and digestibility and retention of dry matter, nitrogen, and ether extract. Performance was not influenced by the dietary inclusion of the ingredient. However, FBM subjected to the highest hydrolysis pressure resulted in the worst overall nutritional balances. The chickens were more susceptible to FBM processing in the pre-starter phase, when the hydrolysis pressure of 2.5 kgf/m² for 30 min provided the best results. In the starter diet, FBM processed at a hydrolysis pressure of 2.0 kgf/m² for 40 min provided the best performance results up to 14 days of age, without changing nutrient metabolism. Up to 9% feather and blood meal can be included in broiler pre-starter and starter diets as long as the ingredient processing method is well-known.

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1. Introduction

Animal-derived ingredients are important inputs in the nutritional, economic, and food-safety aspects of animal diets (Bellaver et al., 2005; Caires et al., 2010; Silva et al., 2014; Beski et al., 2015). Approximately 17% of a bird consists of non-edible wastes that are mainly composed of feathers and offal (8.5 and 6.5%, respectively), with the remaining constituents representing a minimal portion (Olivo et al., 2006).

Despite the widespread use of animal products in the formulation of animal diets, their nutritional value should be better investigated. Restrictions on their inclusion, real chemical and energy composition,

quality and industrial yield, and methods to prevent bacteria proliferation through them must be considered (McCasland and Richardson, 1966; Nunes et al., 2005; Beski et al., 2015).

Feather and blood meal (FBM) is the result of the pressurized cooking of clean and undecomposed feathers. Blood can be included if it does not significantly alter the composition of hydrolyzed feather meal. Feathers are included in practical feeds as part of the protein and amino acid source (Branco et al., 2003; Saima et al., 2008; Baker, 2009).

Xavier et al. (2011) described that up to 6% FBM can be included in diets for broilers in the pre-starter (one to seven days old) and starter (eight to 21 days old) phases. Carvalho et al. (2012), however, stated that the inclusion of 5% feather meal impaired the performance of birds at 35 days of age. Haryanto et al. (2017) found that the use of 2.5% feather meal had positive effects on performance, generating improved feed conversion and reduced lipid profile levels.

Feathers have a high content of crude protein, which is primarily constituted of keratins, simple proteins resistant to proteolytic enzymes in the stomach and intestines of the animal (Scapim et al., 2003). For this reason, they must be hydrolyzed by pressurized steam-cooking to be digested (Isika et al., 2006).

Therefore, standards must be established for the use of poultry slaughterhouse wastes so that their nutritional value can be determined and the effect of their processing methods on poultry production understood. Latshaw (1990) and Shirley and Parsons (2000) found that changes in processing pressure can alter the digestibility of amino acids in feather meal. However, in view of the evolution in the processing of slaughterhouse wastes and in poultry farming, it is important to update the knowledge about the effects of the processing of animal meals on the performance of chickens.

Beski et al. (2015) highlighted the importance of using animal ingredients in poultry diets. According to the researchers, although these ingredients do not supply large amounts of metabolizable energy, their protein and amino acid contents as well as high levels of available phosphorus and some macro- and microminerals can decisively contribute to the balance of diets. Therefore, experiments are warranted to continuously evaluate the processing of feather meal and its impact on broiler performance within the modern context of animal production processes as well as the evolution of methods of slaughter and processing of meat and slaughterhouse wastes.

On this basis, this experiment was developed to evaluate different temperatures and pressures used in the processing of FBM and their effect on nutrient digestibility in broilers.

2. Material and Methods

Two experiments were carried out in the pre-starter (one to seven days of age) and starter (eight to 21 days of age) phases in Goiânia - GO, Brazil (latitude: -16.599288 , longitude: -49.2769467 , 738 m asl). This research project was conducted in accordance with welfare standards proposed by Avila et al. (2007).

For each experiment, 480 male Cobb 500[®] broiler chicks (240 in the pre-starter and 240 in the starter phase) were housed in four galvanized steel batteries with five floors, each having $0.80 \times 0.75 \times 0.25$ m (length \times width \times height) divisions. The batteries were located in a masonry shed covered by French roof tiles and roof lining. Both experiments were laid out in a randomized block design, and the battery floor was the criterion for distribution into the blocks, with four treatments and five replicates of 12 birds each, totaling 20 experimental units for each experiment.

Temperature and relative humidity means during the evaluated period were appropriate for rearing chicken in the initial development phases (Table 1).

The feather and bone meal was obtained from hydrolysis at a slaughterhouse waste processing industry. The processing indices were evaluated according to the capacity of the available equipment and the indication that the pressure applied to the waste could alter its digestibility. In the industry where the ingredient was prepared, the method consisted of applying pressure and temperature in the presence

of moisture to the waste in a conventional batch digester. The pressurized thermal action promotes molecular breaking, resulting in simple protein fractions that can be digested by the gastrointestinal tract of birds.

The feathers were received at the meal and oil factory, pressed, and conducted to the receptor box to be automatically dosed per batch. After loading the 60-min digester, the feathers were hydrolyzed for 50 min at a temperature of 133 °C. This period consisted of 15 min for pressurization to reach 133 °C, 20 min at a constant temperature, and another 15 min for depressurization. Pre-drying was carried out for 70 min and discharge for 20 min. Subsequently, the material was dried in a flash dryer, in a process that consists of heating the cold air with combustion gas from the furnace. The dryer works as follows: the warm air, generated by the exhauster, circulates to promote air movement and particle suspension. The dryer removes 28% of the moisture in 60 min and the 800-kg fixed load is completed with a final moisture of 6 to 8%. The total duration of the process was approximately 260 min per batch. The FBM yield was approximately 3.3% of the live weight.

For both experiments, three internal hydrolysis pressure degrees were applied for three different durations: 2.0 kgf/cm² for 40 min, 2.5 kgf/cm² for 30 min, and 3.0 kgf/cm² for 20 min. The choice of these values followed the principle that hydrolysis time decreases as the degree of internal pressure applied is increased.

After processing, FBM was sprayed with antioxidants and substances for the microbiological control of *Salmonella*. The absence of *Salmonella* in the meals was confirmed by microbiological analysis.

The experimental diets were formulated with 9% FBM differentiated by the processing method (Table 2). Previous experiments conducted by our research group indicated the possibility of using 9% inclusion as the maximum level, which would allow the nutritional effects of processing to be more effectively observed. Diets were formulated to meet the recommendations and composition proposed by the São Salvador Alimentos - SSA company and the Brazilian Tables for Poultry and Swine (Rostagno et al., 2011) (Table 3).

Table 1 - Temperature and relative humidity means during the experimental period, from one to 21 days of age

	Pre-starter phase	Starter phase
Temperature (°C)		
Maximum	33.5	33.8
Minimum	22.0	26.6
Mean	28.0	30.2
Range	11.6	7.2
Relative humidity (%)		
Maximum	58.1	69.4
Minimum	28.5	52.2

Table 2 - Chemical analysis of feather and blood meal (FBM) obtained by processing methods involving different hydrolysis pressures and cooking times

Meal processing	Pre-starter phase			Starter phase		
	% DM	% N.DM	% EE	% DM	% N.DM	% EE
FBM 2.0 kgf/cm ² , 40 min	91.75	13.20	3.89	92.44	12.23	4.97
FBM 2.5 kgf/cm ² , 30 min	92.16	12.89	4.07	91.84	12.32	4.37
FBM 3.0 kgf/cm ² , 20 min	92.23	10.96	3.91	90.18	13.11	4.18
Reference analytical standards for FBM quality control						
PD (%)	A (NaOH/g)	PI (meq/1000 g)	CP (%)	Moisture (%)	Retention in 2.0-mm sieve (%)	
60	0.00	0.00	84	8.0	1.0	

Source: São Salvador Alimentos - SSA.

DM - dry matter; N - nitrogen; EE - ether extract; PD - pepsin digestibility; A - acidity; PI - peroxide index; CP - crude protein.

The average initial weight of the birds was 40.94 ± 0.1 (1st day of age) in Experiment I and 44.47 ± 0.3 (1st day of age) in Experiment II. Birds and diets were weighed on the 1st, 4th, 7th, 14th, 17th, and 21st days of age, and the data were used for the calculation of weight gain, feed intake, and feed conversion. Mortality was recorded daily and expressed as percentage, and dead birds were weighed for performance correction.

The total experimental period was from the 1st to the 21st day of age. In Experiment I (pre-starter phase; days 1-7), the chicks were fed the experimental diets containing FBM subjected to the different processing methods, immediately after being housed. In Experiment II (starter phase; days 8 to 21), the chicks were fed the same diet (Table 3). The same control diet, composed of animal ingredients, was used in both experiments.

Between the 4th and 7th days (Experiment I) and the 17th and the 21st days (Experiment II), a metabolism trial was carried out by the total excreta collection method, twice daily. The collected material was homogenized, weighed, pre-dried in a forced-air oven at 60 ± 5 °C, and subsequently ground in a Wiley mill. Chemical analyses of diets and excreta were performed following the method proposed by Silva and Queiroz (2009).

Table 3 - Composition of the experimental diets

Item	Pre-starter phase (1-7 days)		Starter phase (8-21 days)	
	Control	Feather and blood meal	Control	Feather and blood meal
Ingredient (g/kg)				
Corn grain	521.10	645.20	551.50	680.32
Soybean meal	267.00	176.00	154.07	74.00
Whole soybean	130.20	0.00	210.93	70.20
Meat meal	60.40	70.10	60.20	60.60
Feather and blood meal	0.00	90.00	0.00	90.00
Common salt	3.20	2.60	3.20	2.90
Limestone	0.00	1.00	0.07	0.00
Sodium bicarbonate	1.00	1.00	0.30	0.00
L-threonine	0.50	0.50	0.30	0.40
DL-methionine	3.70	3.00	3.20	2.50
L-lysine HCl 98%	2.00	6.30	1.40	4.90
Choline 60%	0.60	1.40	0.60	1.40
Min./vit. supplement ¹	1.00	1.00	1.00	1.00
Anticoccidial	0.50	0.50	0.60	0.60
Growth promoter	0.50	0.50	1.10	1.10
Antioxidant	0.01	0.01	0.01	0.01
Nutritional composition				
AMEn (kcal/kg)	3.000	2.999	3.119	3.119
Protein (g/kg)	240.51	240.55	220.51	220.52
Calcium (g/kg)	9.90	10.90	9.80	9.80
Available phosphorus (g/kg)	5.00	5.20	4.90	4.90
Digestible threonine (g/kg)	8.10	8.00	7.20	7.20
Digestible met + cys (g/kg)	9.70	9.70	8.80	8.80
Digestible lysine (g/kg)	13.00	13.00	11.60	11.60
Potassium (g/kg)	9.60	6.40	8.80	5.50
Sodium (g/kg)	2.20	2.20	2.00	2.00
Chlorine (g/kg)	3.50	4.40	3.50	4.60
Mongin's number (meq/kg)	243	134	214	100

AMEn - apparent metabolizable energy corrected for nitrogen.

¹ Mineral and vitamin supplement for broilers; provides per kilogram of the product: 3,125,000 IU vitamin A; 550,000 IU vitamin D3; 3,750 mg vitamin E; 625 mg vitamin K3; 250 mg vitamin B1; 1,125 mg vitamin B2; 250 mg vitamin B6; 3,750 mcg vitamin B12; 9,500 mg niacin; 3,750 mg calcium pantothenate; 125 mg folic acid; 350,000 mg DL-methionine; 150,000 mg choline chloride 50%; 12,500 mg selenium; 2,500 mg manganese; 100,000 mg zinc; 100,000 mg iron; 16,000 mg copper; 150,000 mg excipient q.s. (iodine).

The metabolizability coefficient (MC%) of the diets was calculated as proposed by Sakomura and Rostagno (2007):

$$\text{MC (\%)} = (\text{nutrient intake} - \text{nutrient excretion}) / \text{nutrient intake} \times 100.$$

Retention analysis was performed according to Noy and Sklan (2002), considering the nutrient balance and weight gain in the periods of 4-7 days and 17-21 days.

Statistical analyses were carried out using SAEG (version 7.1) software and Tukey's test was applied at the 5% probability level for mean comparison.

The statistical model used in the ANOVA is described below:

$$y_{ij} = \mu + x_i + e_{ij},$$

in which y_{ij} = observed value of response variable Y in treatment x_i ($i = 1, 2, \dots, 7$) and replicate j ($j = 1, 2, \dots, 8$); μ = constant inherent to all observations; $x_i = 2.0 \text{ kgf/cm}^2$ for 40 min, 2.5 kgf/cm^2 for 30 min, or 3.0 kgf/cm^2 for 20 min; and e_{ij} = effect of experimental error associated with observation y_{ij} .

3. Results

The performance evaluation in Experiment I (Table 4) revealed that the treatments did not affect ($P > 0.05$) weight gain, feed intake, or feed conversion of broilers in the pre-starter phase.

In the metabolism trial carried out from days 4 to 7 in Experiment I (Table 5), the dry matter (DM) excretion values decreased as the processing pressure applied to FBM was increased. However, DM intake and balance remained unaltered ($P > 0.05$), indicating that there was no effect of FBM processing method on the absorption rates. Only DM excretion decreased when FBM was processed at 2.5 and 3.0 kgf/cm^2 .

Nitrogen intake and excretion were not affected by the processing of FBM ($P > 0.05$), whereas N balance varied with the degrees of pressure tested (Table 5). The experimental diets containing FBM provided the highest N balance ($P < 0.05$), suggesting that there was an increase in the amount of N retained as compared with diets that did not contain FBM in their composition. Ether extract (EE) intake was reduced ($P < 0.05$) in the groups fed the pre-starter diets containing FBM, with the lowest values obtained when the ingredient was processed at 2.0 kgf/cm^2 for 40 min. Accordingly, EE balance was

Table 4 - Performance of broilers fed pre-starter diets (1-7 days) containing feather and blood meal (FBM) obtained from different processing methods

Variable	Treatment				CV%	P-value
	Without FBM	2.0 kgf/cm ² , 40 min	2.5 kgf/cm ² , 30 min	3.0 kgf/cm ² , 20 min		
1 to 7 days						
Mean weight (g)	176	178	174	168	4.0	0.253
Weight gain (g)	136	137	134	127	5.3	0.263
Feed intake (g)	93	95	93	94	12.9	>0.5
Feed conversion	0.693	0.695	0.689	0.742	12.4	>0.5
8 to 21 days						
Weight gain (g)	650	653	695	644	4.6	0.179
Feed intake (g)	739	776	781	730	5.5	0.310
Feed conversion	1.137	1.192	1.124	1.133	3.9	0.136
1 to 21 days						
Mean weight (g)	831	832	883	808	4.6	0.150
Weight gain (g)	789	790	840	767	4.6	0.145
Feed intake (g)	834	872	880	822	5.6	0.356
Feed conversion	1.058	1.105	1.050	1.070	4.0	0.298

Means followed by different letters in the row differ between each other by Tukey's test at 5% probability.

affected ($P < 0.05$) by the degrees of pressure used in the processing of FBM (Table 5). Among the treatments including FBM, the highest EE balance ($P < 0.05$) was obtained with control and the diet with FBM processed at the hydrolysis pressures of 2.5 kgf/cm², followed by 3.0 and 2.0 kgf/cm².

The results of the metabolism trial obtained in Experiment I (Table 5) revealed that the FBM levels affected ($P < 0.05$) the metabolizability of DM, N, and EE.

The pre-starter diets with inclusion of 9% FBM improved the metabolizability of DM and N as compared with the diet without the ingredient ($P < 0.05$), regardless of the degree of processing to which it was subjected. However, the metabolizability coefficient of EE from the diets with FBM revealed greater digestibility ($P < 0.05$) for FBM processed at 2.5 kgf/cm², followed by 3.0 kgf/cm², and the worst for the hydrolysis pressure of 2.0 kgf/cm², indicating that the higher degree of FBM processing improved the utilization of lipid compounds from the pre-starter diet.

Experiment I also revealed that the treatments affected ($P < 0.05$) N and EE retention (Table 5). The pre-starter diets with 9% FBM also provided better N retention than the diet without FBM. The highest EE retention value ($P < 0.05$) of the diets with FBM was obtained when the ingredient was processed at 2.5 kgf/cm², followed by 3.0 and 2.0 kgf/cm².

In Experiment II, which was conducted with FBM subjected to different hydrolysis pressures and times in the starter phase (eight to 21 days of age), the treatments did not affect ($P > 0.05$) the average weight of the birds on the 14th and 21st days of life (Table 6). However, the experimental diets affected ($P < 0.05$) weight gain and feed conversion from eight to 14 days of age. The diet without FBM resulted in greater weight gain than the diets containing the meal. The best feed conversion ratio ($P < 0.05$) was achieved with the treatments without FBM and with FBM subjected to the hydrolysis pressure of 2.5 kgf/cm² during processing.

However, in the total period (Table 6), the experimental diets had no significant effect on performance ($P > 0.05$). In this case, FBM inclusion did not determine a reduction in performance variables under any of the tested processing methods.

Table 5 - Nutrient metabolizability of starter broiler diets containing feather and blood meal (FBM) obtained from different processing methods, in the period from four to seven days

Variable	Treatment				CV%	P-value
	Without FBM	2.0 kgf/cm ² , 40 min	2.5 kgf/cm ² , 30 min	3.0 kgf/cm ² , 20 min		
Dry matter intake (g)	1.160	1.187	1.149	1.131	3.9	0.333
Dry matter excretion (g)	339a	314ab	298b	293b	6.5	0.045
Dry matter balance (g)	821	873	851	838	3.3	0.139
Nitrogen intake (g) ¹	49.3	52.9	51.1	51.5	3.9	0.186
Nitrogen excretion (g) ¹	20.1	19.1	17.9	17.3	7.2	0.077
Nitrogen balance (g) ¹	29.2b	33.8a	33.1a	34.2a	3.4	<0.001
Ether extract intake (g) ¹	93.5a	64.3d	87.2b	71.1c	3.8	<0.001
Ether extract excretion (g) ¹	24.8	22.3	19.9	18.6	16.8	0.153
Ether extract balance (g) ¹	68.7a	41.9c	67.3a	52.5b	4.9	<0.001
Dry matter MC (%)	70.7b	73.7a	74.1a	74.1a	1.3	0.002
Nitrogen MC (%)	59.2b	63.9a	64.9a	66.4a	2.5	<0.001
Ether extract MC (%)	73.4a	65.8c	77.3a	74.4b	5.7	0.006
Dry matter retention (mg/g)	754.3	799.6	806.9	852.6	5.0	0.072
Nitrogen retention (mg/g)	36.9b	47.7a	49.1a	53.2a	9.1	0.003
Ether extract retention (mg/g)	63.3a	38.2c	64.0a	53.2b	7.6	<0.001

MC - metabolizability coefficient.

¹ Dry-matter basis.

Means followed by different letters in the row differ between each other by Tukey's test at 5% probability.

The metabolism trial carried out from the 17th to the 21st days in Experiment II (Table 7) indicated a lack of effects ($P>0.05$) on the intake, excretion, balance, metabolizability coefficient, and retention of DM, N, and EE.

In the starter phase, the FBM processing methods induced different responses from N intake. The chickens fed the diet containing FBM processed at 3.0 kgf/cm² for 20 min obtained the best results for this variable in comparison with control group ($P<0.05$). The groups fed the diet containing FBM processed at 2.0 kgf/cm² for 40 min and 2.5 kgf/cm² for 30 min were similar to each other, to control group, and to the group which received the diet with FBM processed at 3.0 kgf/cm² for 20 min, for N intake.

Table 6 - Performance of broilers fed starter diets (8-21 days) containing feather and blood meal (FBM) obtained from different processing methods

Variable	Treatment				CV%	P-value
	Without FBM	2.0 kgf/cm ² , 40 min	2.5 kgf/cm ² , 30 min	3.0 kgf/cm ² , 20 min		
8 to 14 days						
Mean weight (g)	491	462	475	470	3.2	0.159
Weight gain (g)	301a	273b	288ab	278b	4.1	0.049
Feed intake (g)	322	319	324	352	7.0	0.278
Feed conversion	1.068b	1.176ab	1.123b	1.263a	5.5	0.022
1 to 21 days						
Mean weight (g)	905	832	837	850	5.3	0.219
Weight gain (g)	756	686	693	703	5.9	0.201
Feed intake (g)	813	788	786	827	7.1	>0.5
Feed conversion	1.075	1.146	1.134	1.176	4.1	0.127

Means followed by different letters in the row differ between each other by Tukey's test at 5% probability.

Table 7 - Nutrient metabolizability of broiler diets containing feather and blood meal (FBM) obtained from different processing methods, in the period from 17 to 21 days

Variable	Treatment				CV%	P-value
	Without FBM	2.0 kgf/cm ² , 40 min	2.5 kgf/cm ² , 30 min	3.0 kgf/cm ² , 20 min		
Dry matter intake (g)	3.306	3.562	3.344	3.690	7.3	0.349
Dry matter excretion (g)	966	858	769	954	12.5	0.202
Dry matter balance (g)	2.341	2.704	2.576	2.736	11.7	>0.5
Nitrogen intake (g) ¹	162b	175ab	174ab	202a	7.6	0.043
Nitrogen excretion (g) ¹	54	53	55	65	17.4	>0.5
Nitrogen balance (g) ¹	108	122	119	137	10.2	>0.5
Ether extract intake (g) ¹	296	275	256	284	7.3	10.2
Ether extract excretion (g) ¹	76	47	31	63	33.1	>0.5
Ether extract balance (g) ¹	219	228	225	222	15.5	>0.5
Dry matter MC (%)	70.2	75.8	75.8	73.8	5.6	>0.5
Nitrogen MC (%)	65.8	69.1	67.1	67.7	6.9	>0.5
Ether extract MC (%)	73.1	82.4	86.1	77.2	9.2	0.293
Dry matter retention (mg/g)	869.2	978.7	915.2	959.3	11.7	>0.5
Nitrogen retention (mg/g)	39.8	43.6	42.4	47.7	11.0	0.388
Ether extract retention (mg/g)	80.6	82.1	79.3	77.6	14.1	>0.5

MC - metabolizability coefficient.

¹ Dry-matter basis.

Means followed by different letters in the row differ between each other by Tukey's test at 5% probability.

4. Discussion

The performance evaluation in Experiment I (Table 4) revealed that the treatments did not affect the weight gain, feed intake, or feed conversion of broilers in the pre-starter phase.

In experiments conducted with the same ingredient evaluated in this experiment, Xavier et al. (2011) observed that the inclusion level of 6.0% in broiler pre-starter diet worsened performance up to 21 days of age, eliciting a negative linear response from weight gain and feed intake, but no changes in feed conversion. The authors recommended the inclusion of 3 to 4% in the broiler pre-starter and starter phases.

Nonetheless, Baker et al. (1981) supplemented methionine and lysine to feather meal and concluded that it can replace up to 40% of CP in the feed. In meat quail, Santos et al. (2006) found that up to 9.0% inclusion of feather meal caused a linear decrease in intake from one to 21 days of age, having no effect on the other variables tested in the protocol. Caires et al. (2010), on the other hand, found that the inclusion of 5% of the ingredient did not interfere with performance, but resulted in decreased costs. Hasni et al. (2014) suggested that the inclusion of 6.5 to 6.8% feather meal in the diet can replace fish meal and provide similar performance, at a lower cost, in chickens. Lastly, Haryanto et al. (2017) evaluated inclusion levels of up to 10% of the product in the diet and found that feed conversion was improved at 2.5%. However, the authors did not test the effects of variations in ingredient processing on broiler performance.

The DM balance results remained unaltered, indicating that there was no effect of the FBM processing method on the absorption rates in the pre-starter phase. Only DM excretion decreased when FBM was processed at 2.5 and 3.0 kgf/cm².

There are many factors related to improved utilization of nutrients from animal-derived ingredients. Papadopoulos et al. (1985) concluded that the temperature, pressure, and processing time of feather meal were considered primary factors affecting the protein quality of this ingredient. Batterham et al. (1986) increased the retention time and temperature in the processing of meat and bone meal and found decreased availability of amino acids, especially lysine. Papadopoulos et al. (1986) found that, with the increase in hydrolysis time, cysteine decreased whereas N solubility increased. Wang and Parsons (1997) noted that a negative aspect of the thermal process is the degradation of thermolabile amino acids, which compromises the quality of feather meal. Baker et al. (1981) observed that the reduced digestibility of cysteine and methionine is due to the processing of the meal, in which cysteine is transformed into lanthionine.

As regards the metabolism of N compounds, Shirley and Parsons (2000) found that increasing processing pressures (0, 30, and 60 psi) reduced the digestibility of amino acids from feather meal. Similarly, Moritz and Latshaw (2001) found that higher processing pressures (207 to 724 kPa or 2.0 to 7.0 kgf/cm²) of feather meal reduced amino acid digestibility, and the average density of the meal in kg/m³ increased as the pressure was elevated in a constant time.

Because the apparent metabolizable energy corrected for nitrogen (AMEn) values of animal byproducts are highly variable, processing emerges as a tool to adjust the characteristics of the desired product.

Bellaver et al. (2001) observed a significant difference in AMEn when FBM was processed in a fixed load digester at a pressure of 3.0 atm. When hydrolysis time was increased from 30 to 60 min, AMEn went from 2,414 to 2,713 kcal/kg. This effect was not observed for the pressures of 2.0 and 3.0 atm in a fixed time.

The inclusion of FBM did not determine a reduction in performance variables in any of the studied processing methods. These results are similar to those found by Xavier et al. (2011), who evaluated increasing levels (0, 2, 4, and 6%) of FBM in the broiler starter diet and observed no effects on weight gain, feed intake, or feed conversion. Nevertheless, the diet with FBM turned out to be economic, as it increased nutrient and energy diversity in poultry diets.

Xavier et al. (2011) used the same ingredient and observed a quadratic effect on the metabolizability of DM and EE, but no effect for N, disagreeing with the present study. Eaksuree et al. (2016), in turn, found that N retention ranged from 48 to 85% and EE digestibility varied between 63 and 88% following the inclusion of the keratinase enzyme in the diet.

In the starter phase, the FBM processing methods resulted in differences in weight gain and feed conversion from eight to 14 days of age. The broilers fed the diet with FBM subjected to the hydrolysis pressure of 2.5 kgf/cm² for 30 min and the diet without FBM had the best performance.

The increase in hydrolysis time decreases digestibility and may affect the final quality of FBM. In the present study, 60% digestibility was obtained in 30 min of processing at 2.5 kgf/cm² of pressure. Sinhorini (2013) evaluated the *in vitro* digestibility of FBM and found that both variables, pressure and hydrolysis time, were significant in the processing of the meals, which showed a protein content of 83.44% and a true digestibility coefficient of 43.72% at the pressure of 2.0 kgf/cm² under 40 min of hydrolysis. Eyng et al. (2012) concluded that the chemical composition of byproducts may vary depending on thermal processing, percentage of inclusion, and origin of the ingredients, which are not constant and may be attributed to low standardization and to the type and proportion of constituents.

5. Conclusions

The diet with feather and blood meal subjected to the hydrolysis pressure of 2.5 kgf/cm² for 30 min is the most adequate for the broiler pre-starter phase. Feather and blood meal processed at a hydrolysis pressure 2.0 kgf/m² for 40 min provides the best performance and nutrient metabolizability results. Up to 9% feather and blood meal can be included in pre-starter and starter diets as long as the ingredient processing is well-known. Therefore, it is crucial to analyze the production process and establish the nutritional characteristics of the desired product in advance.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: J.H. Stringhini. Formal analysis: N.S.M. Leandro. Funding acquisition: R.M. Jardim Filho. Investigation: M. Laboissière. Methodology: M. Laboissière and J.H. Stringhini. Project administration: M. Laboissière and J.H. Stringhini. Resources: R.M. Jardim Filho. Supervision: M.B. Café and J.H. Stringhini. Validation: N.S.M. Leandro and M.B. Café. Writing-review & editing: M.A. Costa and J.H. Stringhini.

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