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ABSTRACT

Studies were conducted to evaluate the nutritional value and inclusion levels of babassu meal **(BM)** in the diet of grower layer pullets in substitution to wheat meal. Digestibility, metabolism and growth trials were conducted. Twelve cecectomized roosters were used in the digestibility assay to determine the coefficients of standardized digestibility of amino acids **(CSDAA)**. The metabolism trial was conducted with 30 adult roosters to determine the apparent metabolizable energy corrected for nitrogen **(AMEn)** of BM. A growth trial was performed to determine replacement levels of wheat midds by BM diet using 360 six-week-old commercial layer pullets. BM was included at the 0, 75 and 150 g/kg of BM, during grower and development rearing phases, respectively. Feed intake, body weight gain, and feed conversion were evaluated. BM AMEn was determined as 1,474 kcal/kg, on as-fed basis. The CSDAA determined for BM were below 88% for all AA. The inclusion of BM in the feed of grower layers (7-18 week) significantly decreased feed intake ($p<0.05$), but significantly improved body weight gain and feed conversion ratio ($p<0.05$) at 15% inclusion level. Considering the nutritional value and performance results, BM can replace wheat midds in diets of grower layer pullets.

INTRODUCTION

The evaluation of nutrient composition, level, and availability, as well as energy concentration and availability in alternative feed ingredients is essential for feed formulation and to reduce feed costs (Rostagno *et al*., 2007). In addition, the commercial availability and physical characteristics of these ingredients also need to be assessed (Belaver & Ludke, 2004), because of their wide variability (Albino, 1991; Tucci *et al*., 2003).

There are many alternative feedstuffs sold in the market of the northeast region of Brazil, and these may aid the development of poultry production in the region if properly used (CARNEIRO, 2012). In the state of Maranhão, babassu (*Orbignya* ssp) by-products are widely available. This palm tree is planted in an area of 10 million hectares in that state (DESER, 2007). The babassu fruit has four components: the epicarp is the most external layers, and consists of fibers, representing 11% of the fruit; the mesocarp (23%) is rich in starch and other substances; the endocarp accounts for 59% of the fruit; and the kernel (7%) contains about 60% of oil. Babassu is planted mostly for oil production (Soler *et al*., 2007).

Babassu kernel production in Brazil reached 118,723 tons in 2005, and the state of Maranhão produced 111,730 tons or 94% of total Brazilian production (IBGE, 2006). Babassu meal (BM) is a by-product of oil extraction by chemical solvents or mechanical crushing (Teixeira, 2003). BM is considered palatable and may potentially be used in animal feeds due to its protein, fat, and fiber levels (Teixeira, 2003).

There are few studies in literature on the inclusion of babassu meal (BM) in the feed of monogastric animals. Jatahy (1997) obtained higher birth weight in piglets from sows fed BM relative to wheat midds. Carneiro *et al*. (2009) found that up to 8% BM can be included in the diet of 22- to 42-d-old broilers with no detrimental effects on feed intake, weight gain, or feed conversion ratio. According to Santos Neta *et al*. (2011), the inclusion of up to 12% BM in starter broiler diets does not affect feed intake, weight gain, or feed conversion ratio.

Babassu meal composition is not very different from that of wheat midds, and therefore, could potentially replace the latter in development layer pullets.

The objective of this study was to evaluate the nutritional value and inclusion levels of babassu meal in pullet layer feeds during the development phase.

MATERIALS AND METHODS

Digestibility, metabolism, and performance trials were carried out. The digestibility and metabolism assays were performed with roosters at the Poultry Science Laboratory of the Department of Animal Science of FCAV/UNESP, Jaboticabal campus, Brazil. The live performance trial, aimed at evaluating BM inclusion levels for developing layer pullets, was carried out at the Poultry Experimental Unit "José dos Reis Ataíde", of the Agricultural Science Center of Universidade Estadual do Maranhão, São Luís, state of Maranhão, Brazil.

Babassu meal origin and processing

The evaluated BM was acquired from OLEAMA (Oleaginosas Maranhense), a company that processes babassu kernel in São Luis, MA, Brazil. The BM results from the industrial process of oil extraction from babassu kernel after grinding, cooking, pressing, filtration, and extraction with a solvent. Kernel processing involves laminating the kernel in slivers and successive immersions in hexane until oil is extracted. The solvent is continuously recovered by evaporation and distillation, and the resulting products are crude oil and pelleted babassu meal.

Chemical and energy composition

In order to determine the chemical and energy composition, the acquired BM was analyzed for dry matter (DM), nitrogen (N) and N converted into crude protein (CP=N*6.25), ether extract (EE), neutral detergent fiber (NDF), and acid detergent fiber (ADF) at the Animal Nutrition Laboratory of FCAV/UNESP, Jaboticabal campus, according to the methods described by Silva & Queiroz (2002). Gross energy (GE) was determined in adiabatic bomb calorimeter (1281, PARR Instrument, USA). Amino acid composition was determined by HPLC at the Laboratory Centro de Apoio Nutricional (CEAN) of Adisseo Brasil Nutrição Animal in Santa Maria, state of Rio Grande do Sul, Brazil.

Determination of apparent digestibility coefficients of amino acids

The standardized digestibility coefficients of BM amino acids were determined using the methodology of precise feeding (Sibbald, 1976), as described by Sakomura & Rostagno (2007) with cecectomized adult roosters. In total, 12 Bovans White® roosters were individually housed in metabolic cages and distributed into two treatments with six replicates of one bird each. Treatments consisted of birds fed BM and fasted birds for the collection of endogenous and metabolic losses (EML).

Birds were initially submitted to 48-h fasting to empty their digestive tract. Birds of the EML treatment were fasted for further 48 h for excreta collection. The birds in the BM treatment were fed 40 g of BM by gavage directly in the crop, as described by Sibbald (1976), after which they were taken to the cages. Excreta collection was immediately started, using a collecting plastic bag. As a precaution, collecting trays were also placed under the cages. Excreta collection of the EML birds simultaneously started. Excreta were collected for 48 h after birds were fed. In order to prevent microbiological spoilage of the excreta, a maximum interval of 12 h between collections was adopted.

The collected excreta were identified per replicate, frozen, freeze-dried, and analyzed for DM and amino acid content, as previously described. Based on these analyses, BM intake, excreta output, and on the analysis of the endogenous fraction obtained from fasted roosters, the standardized digestibility coefficients of BM amino acids were calculated according to the equation described by Sakomura & Rostagno (2007).

Determination of BM energy values

The methodology of total excreta collection, according to the protocol described by Sakomura & Rostagno (2007), was used to determine digestibility coefficients and apparent metabolizable energy (AME) and apparent metabolizable energy corrected for nitrogen (AMEn) values. Thirty Bovans White® roosters were housed in galvanized iron cages and randomly allotted to two treatments (diets), with five replicates of two birds each. Diets consisted of a reference diet formulated to supply the birds' nutritional requirements (Rostagno *et al*., 2005), containing 3,050 kcal AMEn and 148 g CP per kg. The test diet consisted of 75% of the reference diet and 25% BM, on as-is basis.

A 10-d experimental period, with five days of adaptation and five days of excreta collection, was applied. Trays lined with plastic were placed under the cages for excreta collection. One g ferric oxide per kg of diet was added to both feeds on the first and the last day of collection to allow identifying the first and last collection day. Excreta with no marker on the first day of collection and those with the marker on the last day were discarded. Excreta were collected twice daily. Total feed intake and total excreta output were determined at the end of the experimental period.

The collected excreta were identified per replicate, frozen, freeze-dried, and submitted to analyses. After drying, excreta samples were ground in a micro-mill and submitted to the laboratory, together with samples of the test and reference diets for DM, GE, and N determination, according to the methods described by

Table 1 – Ingredients and calculated composition of the experimental diets (g/kg)

Ingredients	7-12 weeks			13-18 weeks		
	0	75	150	0	75	150
Corn grain	618.0	618.8	620.3	689.1	691.2	694.0
Soybean meal 45	188.8	184.0	178.2	131.5	126.5	121.3
Wheat midds	150.0	75.0	0.0	150.0	75.0	0.0
Babassu meal	0.0	75.0	150.0	0.0	75.0	150.0
Dicalcium phosphate	14.0	14.7	15.3	9.8	10.5	11.1
Soybean oil	12.6	16.5	20.2		2.8	5.3
Limestone	10.5	9.5	8.5	12.7	11.7	10.7
Salt	3.6	3.6	3.6	3.3	3.3	3.3
Vitamin premix[1]	1.0	1.0	1.0	1.0	1.0	1.0
Choline chloride 60	0.7	0.7	0.7	1.0	1.0	1.0
Mineral premix[2]	0.5	0.5	0.5	0.7	0.7	0.7
DL-Methionine 99	0.2	0.6	1.0	0.5	0.5	0.5
L-Lysine HCL 78	0.0	0.0	0.5	0.4	0.7	0.7
BHT	0.1	0.1	0.1	-	-	0.4
Total	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0
Calculated composition						
AMEn (kcal/kg)	2900	2900	2900	2900	2900	2900
Crude protein (g/kg)	160.0	160.0	160.0	140.0	140.0	140.0
Crude fiber (g/kg)	35.4	46.5	57.8	33.5	44.7	56.0
Lysine* (g/kg)	6.2	6.2	6.2	5.5	5.0	4.8
Methionine (g/kg)	2.6	2.9	3.0	2.5	2.6	2.6
Methionine + cystine (g/kg)	4.9	5.1	5.0	4.7	4.6	4.6
Threonine (g/kg)	5.2	4.8	4.5	4.5	4.1	4.1
Calcium (g/kg)	8.3	8.3	8.3	8.0	8.0	8.0
Available phosphorus (g/kg)	3.9	3.9	3.9	3.1	3.1	3.1
Sodium (g/kg)	1.6	1.6	1.6	1.5	1.5	1.5
Chlorine (g/kg)	2.6	1.6	1.6	2.4	2.4	2.4
Potassium (g/kg)	6.7	6.2	5.7	5.8	4.8	4.8

[1] Vitamin premix (amount/kg product) – Vit. A – 2,666,000 IU, Vit. B1 - 600 mg, Vit. B2 – 2,000 mg, Vit. B6 – 933.10 mg; Vit. B12 – 4,000 mcg; Vit. D3 – 666.50 mg; Vit. E – 5,000 IU; Vit. K - 600 mg, folic acid - 333.25 mg, pantothenic acid – 5,000 mg, biotin - 20 mg, choline – 133,330 mg,

niacin - 13.333 mg, selenium - 100 mg, vehicle Q.S.P. - 1000 g.

[2] Trace mineral premix (amount/kg product) -Mn – 150,000 mg, Zn – 100,000 mg, Fe – 100,000 mg, Cu – 16,000 mg, I – 1,500 mg *Formulation based on digestible amino acids

Silva & Queiroz (2002). The coefficients of apparent digestibility and apparent metabolizable energy (AME) and apparent metabolizable energy corrected for nitrogen (AMEn) were calculated using the equations proposed by Matterson *et al*. (1965).

Evaluation of babassu meal inclusion levels in the feeds

In the experiment, 360 Dekalb White® layer pullets between seven and 18 weeks of age were used. Birds were individually weighed to obtain even weight distribution among the experimental units, and allotted according to a completely randomized experimental design to three treatments with six replicates of 20 birds each. Treatments consisted of iso-energy and iso-protein diets containing 0, 75 or 150 g BM/kg. BM was added at the expense of wheat midds.

Feeds were formulated according to the birds' nutritional requirements and feedstuff (corn, soybean meal, wheat midds, oil, phosphate, and limestone) composition proposed by Rostagno *et al*. (2005) and the BM composition determined in this study for the rearing (7-12 weeks) and development (13-18 weeks) phases, as shown in Table 1.

Body weight (BW, kg/bird), weight gain (WG, kg/bird), feed intake (FI, kg/bird) and feed conversion ratio (FCR, kg/kg) were determined. Birds were weighed in the beginning and at the end of each phase to calculate weight gain. Feed offer and feed residues of each experimental unit were recorded per phase to determine average feed intake. Feed conversion ratio was corrected for mortality, as described by Sakomura & Rostagno (2007).

The assumptions of error normality and homoscedasticity were tested by tests of Cramer-von-Mises and Levene, respectively, at $P<0.05$. As data were quantitative, orthogonal contrasts were evaluated, considering linear and quadratic effects. Statistical analysis was carried out using SAS® software package (version 9.1, SAS Institute Inc., USA).

RESULTS AND DISCUSSION

Babassu meal chemical and energy composition

Chemical composition (g/kg) and gross energy (kcal/kg) values of the evaluated BM are shown in Table 2. The obtained CP values are close to those reported in literature of 173 (Embrapa, 1991), 175 (Valadares Filho *et al*., 2006), and 202 (Rostagno *et al*., 2011).

The high crude fiber content determined (273.3 g/kg) was much lower than the 475.2 g/kg reported by Rostagno *et al*. (2011), but close to the 25.93% value observed by Embrapa (1991; 259.3 g/kg) and Silva (2009; 295 g/kg). Other feedstuffs present similar crude fiber levels as BM, such as cottonseed meal (249.3 g/kg), soybean hulls (327.0 g/kg), and sunflower meal (257.2 g/kg), all of which are by-products of oil extraction. The obtained values of 674 g NDF/kg and 475.5 ADF/kg are different from those reported by other authors (Valadares Filho *et al*., 2006; Silva, 2009; Rostagno *et al*., 2011).

Table 2 – Chemical and energy composition of babassu meal, expressed on DM basis[1]

Chemical composition[2]	Unit	Level
Dry matter	g/kg	911.4
Crude protein	g/kg	182.1
Ether extract	g/kg	34.3
Crude fiber	g/kg	273.3
Ashes	g/kg	42.6
Neutral detergent fiber	g/kg	674
Acid detergent fiber	g/kg	475.5
Gross energy	kcal/kg	4321
Calcium	g/kg	0.44
Total phosphorus	g/kg	9.33
Potassium	g/kg	7.57
Magnesium	g/kg	2.74
Sodium	g/kg	6.58
Chlorine	mg/kg	0.14
Copper	mg/kg	0.02
Iron	mg/kg	0.16
Manganese	mg/kg	0.21

[1] An aliquot of a sample of 100 kg babassu meal was analyzed; [2] All analyses were performed in duplicate.

Babassu meal EE content was higher than the 21.5 g/kg observed by Rostagno *et al*. (2011). The different fat contents in BM may be due to different babassu kernel processing methods.

Gross energy content was close to that found by Rostagno *et al*. (2011; 4,207 kcal/kg), but was lower than the values obtained by Santos Neta *et al*. (2011) and Silva (2009), of 4,847 and 5,056 kcal/kg, respectively, which may be explained by the higher oil content remaining in the BM after babassu kernel processing. According to Rostagno *et al*. (2011), other feedstuffs present GE values similar or close to BM: rice meal, brewer's yeast, canola meal, cottonseed meal, peanut meal, sunflower meal, wheat midds, coconut meal, and soybean hulls. The difference between the GE values found in the present study relative to literature reports may be explained by the differences in the processes to obtain these by-products. This variability warrants further studies to determine the chemical composition of BM with higher accuracy.

Determination of BM energy values

Apparent metabolizable energy (AME), apparent metabolizable energy corrected for nitrogen (AMEn), and the coefficients of apparent digestibility of dry matter are shown in Table 3.

The obtained AME value was higher than that found by Rostagno *et al*. (2011, 1116 kcal/kg), and lower than those reported by Embrapa (1991, 1932 kcal/kg) and Almeida *et al*. (2011, 1116 kcal/kg). The metabolizable proportion of the analyzed GE (AMEn/GE) was 37.43%, suggesting the low assimilation of energy during digestion and metabolism, with a loss of approximately 62.57% of GE. This indicates that the low efficiency of energy utilization by the birds may be related to the high fiber content of BM. Silva (2009) obtained 2650 kcal/kg AME when evaluating BM energy using the traditional method of total excreta collection in growing broilers. In that study, BM presented high ether extract content (8.81%), which suggests higher oil retention in the meal after processing, thereby resulting in the higher AME value.

Table 3 – Means and standard error of apparent metabolizable energy (AME), and apparent metabolizable energy corrected for nitrogen (AMEn), and coefficient of apparent digestibility of dry matter (CADDM) of babassu meal.

Parameters	Values
AME (kcal/kg as fed)	1549 ± 59.90
AMEn (kcal/kg as fed)	1474 ± 59.43
CAMDM (%)	23.19 ± 1.41

Total and digestible amino acid values and coefficients of amino acid digestibility

Total amino acid values, coefficients of standardized digestibility of amino acids (CSDAA) and digestible amino acid values are presented in Table 4. The coefficients were lower than those reported by Rostagno *et al*. (2011). In general, BM amino acid profile is lower compared with other protein feedstuffs, particularly relative to the limiting AA methionine and lysine.

The CSDAA of BM were lower than 88% for all AA. Among the essential AA, leucine presented the lowest average digestibility (62.18%), and among the non-essential AA, the lowest average digestibility was presented by serine (42.15%). The highest average coefficient of digestibility was obtained with phenylalanine (87.72%) for the essential AA, and with cystine (80.70%) for the non-essential AA. The coefficients of digestibility of babassu meal described by Rostagno *et al*. (2011) are close to those obtained in the present study.

Table 4 – Total amino acids (total AA), coefficients of standardized digestibility (CSDAA), and digestible amino acid (digestible AA) values of babassu meal[1].

Amino acids	Total AA	CSDAA[2]	Digestible AA[3]
	g/kg	(%)	(g/kg)
Methionine	0.6	83.72	0.5
Cystine	0.6	80.70	0.5
Met+Cys	1.2	82.21	1.0
Lysine	0.9	68.44	0.6
Threonine	3.3	87.70	2.9
Arginine	8.6	66.27	5.7
Isoleucine	1.9	65.28	1.2
Leucine	3.8	62.18	2.4
Valine	3.3	63.22	2.1
Histidine	0.7	63.17	0.4
Phenylalanine	2.3	87.72	2.0
Tyrosine	1.0	51.79	0.5
Serine	2.0	42.15	0.8
Glycine	1.9	74.67	1.4
Alanine	0.6	64.82	0.3
Proline	1.2	76.22	0.9
Aspartic acid	3.7	50.10	2.0
Glutamic acid	9.2	66.86	6.2

[1] Values expressed on dry-matter basis; [2] Coefficient of standardized digestibility of amino acids; [3] Digestible amino acids

Evaluation of babassu meal inclusion levels in the feeds

The results of the statistical analyses and average feed intake, body weight, weight gain, and feed conversion ratio of growing layer pullets are shown in Table 5. The assumptions of error normality and homoscedasticity were tested and confirmed, as shown by the results presented in Table 5.

Table 5 – Feed intake (FI, kg/bird), body weight (BW, kg), weight gain (WG, kg/bird), and feed conversion ratio (FCR, kg/kg) of growing layer pullets fed diets with different babassu meal levels.

Levels	FI	BW	WG	FCR
7 to 12 week of age				
0 g/kg BM	2.033	0.907	0.573	3.57
75 g/kg BM	2.102	0.906	0.571	3.68
150 g/kg BM	1.977	0.953	0.618	3.22
Statistics				
F for treatment	7.52*	3.58*	3.43*	5.38*
F for linear effect		5.25*	4.98*	5.71*
F for quadratic effect	12.04*			5.05*
Levene test	1.74^{NS}	3.71^{NS}	3.35^{NS}	4.66^{NS}
CVM Test	0.04^{NS}	0.38^{NS}	0.04^{NS}	0.03^{NS}
CV (%)	2.73	3.71	5.95	7.37
13 to 18 week of age				
0 g/kg BM	2.502	1.200	0.428	5.91
75 g/kg BM	2.433	1.206	0.409	6.01
150 g/kg BM	2.305	1.229	0.425	5.48
Statistics				
F for treatment	4.46^{NS}	0.17 NS	2.07^{NS}	0.69^{NS}
Levene test	1.27^{NS}	0.11^{NS}	1.65^{NS}	0.03^{NS}
CVM Test	0.54^{NS}	0.03^{NS}	0.05^{NS}	0.13^{NS}
CV (%)	5.28	11.84	3.44	11.57
7 to 18 week of age				
0 g/kg BM	4.451	1.200	0.858	5.19
75 g/kg BM	4.545	1.206	0.863	5.27
150 g/kg BM	4.298	1.229	0.908	4.74
Statistics				
F for treatment	2.92^{NS}	0.65^{NS}	2.19^{NS}	13.63*
F for linear effect				17.18*
F for quadratic effect				10.08*
Levene test	0.75^{NS}	1.04^{NS}	1.30^{NS}	1.67^{NS}
CVM Test	0.11^{NS}	0.04^{NS}	0.07^{NS}	0.03^{NS}
CV (%)	4.03	3.79	5.34	3.82

CVM: Cramer-von-Mises test; CV: coefficient of variation
* $p<0.05$
^{NS} $p>0.05$

Dietary BM levels were studied by orthogonal contrasts, assuming linear or quadratic effects. Differently from polynomial regression, this analysis only determined if the variation in the response parameter was constant (linear) or variable (quadratic) as a function of increasing BM levels in the diet.

Therefore, in the phase of 7-12 weeks of age, the inclusion of BM in the feed had a quadratic effect (p=0.0034) on feed intake, i.e., feed intake increased as BM dietary level increased. At the BM inclusion level of 150 g/kg, crude fiber increased from 35.4 to 57.8 g/kg, reducing feed intake.

However, despite the reduction in feed intake, there was a positive linear effect on weight gain (p=0.0414) and body weight (p=0.0368) and a quadratic effect on feed conversion ratio (p=0.0401), with the lowest feed conversion ratio obtained in the pullets fed 150 g/kg BM. According to Gonzales-Alvarado *et al*. (2007) and Araujo *et al*. (2008), the inclusion of low fiber levels in the diet of growing layer pullets promotes the development of the digestive tract and therefore, has positive effects on nutrient digestion and efficiency of utilization.

During the development phase (13-18 weeks of age), feed intake, body weight, weight gain, and feed conversion ratio were not affected by the dietary inclusion of BM. The results show that increasing crude fiber levels to 5.60%, as in the diet with the highest BM level, completely replacing wheat midds, did not affect feed intake and promoted the same performance as the pullets fed the diet with wheat midds. This indicates that babassu meal can completely replace wheat midds in the development diet of layer pullets.

Considering the entire period (7-18 weeks of age), feed intake, body weight, and weight gain were not influenced by dietary BM inclusion levels. However, there was a quadratic effect (p=0.0063) on feed conversion ratio, indicating that birds responded to the treatments, with the lowest ratio obtained in pullets fed 150 g/kg of BM. The higher fat content of this feed may have allowed better nutrient utilization, with consequent improvement of feed conversion ratio. A study showed that the economic limitation of fiber-rich ingredients occurs before biological limitation due to the need to add oil to the feeds (Silva *et al*., 2009a).

According to the nutritional value and performance results obtained in the present study, wheat midds can be replaced by babassu meal in the diet of development layer pullets.

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