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Nitrogen-corrected apparent metabolizable energy value of macadamia nut cake for broiler chickens determined by difference and regression methods

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ABSTRACT

Two energy balance experiments were conducted to determine the AME_n value of Macadamia nut cake (MNC) for broiler chickens at different ages. In experiment 1, two dietary treatments were fed from 4 to 10 d of age. Dietary treatments consisted of a basal diet (no MNC) and a diet containing 60 g/kg of MNC (940 g/kg of basal diet + 60 g/kg of MNC). In experiment 2, four dietary treatments were provided from 17 to 23 d of age. Diets in second experiment were 1) basal control diet (no MNC); 2) 30 g/kg of MNC (970 g/kg of basal diet + 30 g/kg of MNC); 3) 60 g/kg of MNC (940 g/kg of basal diet + 60 g/kg of MNC); and 4) 90 g/kg of MNC (910 g/kg of basal diet + 90 g/kg of MNC). In experiment 2, broilers were restricted feeding in such a way that all the birds received the same amounts of basal diet, so that differences in AME_n consumption were only due to MNC. A single source of MNC was used in both experiments. Feed intake, body weight, energy intake, energy excretion, N intake, N excretion, AME_n intake and AME_n were determined in both experiments. In experiment 1, the AME_n was estimated using the difference method by subtracting AME_n of the basal diet from AME_n of the test diet. In experiment 2, AME_n intake was regressed against feed intake with the slope estimating AME_n of MNC. Regression equation used was Y = 2,908.2x − 122.73 ($P < 0.001$; SEM of the slope = 11.7; $r^2 = 0.93$). The AME_n of MNC was found to be 12.09 and 12.17 MJ/kg in experiment 1 and 2, respectively with an average of 12.13 MJ/kg on DM basis. The results indicate that AME_n of MNC is comparable to conventional feedstuffs with similar nutrient profile, thus can be incorporated in broiler diets.

1. Introduction

Nutritionists and producers are continuously looking for potential feedstuffs to include in poultry diets which can fulfill the nutritional requirements of poultry and reduce feed costs. Energy and protein are the most expensive components of poultry diets, thus the variation in the cost of energy/protein yielding feedstuffs will increase the cost of poultry production. Corn and wheat are still the most widely used energy feedstuffs in poultry diets (Mateos et al., 2007; Amerah et al., 2008; Kong and Adeola, 2014). A possible way to reduce poultry feed costs is finding alternatives to conventional protein sources that are

Abbreviations: AA, amino acids; ADF, acid detergent fiber; ADL, acid detergent lignin; AME_n, apparent metabolizable energy corrected by nitrogen; CP, crude protein; DM, dry matter; FI, feed intake; GE, gross energy; GEE, gross energy excreta; GEI, gross energy intake; MNC, macadamia nut cake; NDF, neutral detergent fiber; NE, nitrogen output from excreta; NI, nitrogen intake

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inexpensive, efficient and locally available (Cao and Adeola, 2016).

Macadamia nut cake (MNC) is a by-product of macadamia nut oil extraction industry, which is available in Hawaii (USA), Australia, New Zealand, Kenya, Brazil, Israel and elsewhere in the world. The MNC is not well utilized in animal feeding programs due to limited information on its nutritional value. But, it has potential to be utilized as a cost-effective feed ingredient in animal diets as it is a by-product containing high level of energy, fat, and a fair to high amount of protein (Acheampong-Boateng et al., 2008; Skenjana, 2011; Tiwari and Jha, 2017). However, limited or no information is available on nutritional value of MNC for broiler which limits its use in broiler's feeding program. The apparent metabolizable energy corrected by nitrogen (AME_n) is widely accepted for describing requirements, formulating diets and foremost to characterize new feedstuff (NRC, 1994). The MNC being fair to rich in protein, it is necessary to consider nitrogen retention as we expect reduction in the corrected metabolizable energy (Lopez and Leeson, 2007). It also decreases the variation in estimate of metabolizable energy of ingredients flexible in protein content (Leeson et al., 1977). So, it is prerequisite to have AME_n value of MNC to be incorporated in poultry diets. The objective of this study was to determine the AME_n of MNC for broiler chicken in two experiments using the difference method from 4 to 10 d of age (experiment 1) and regression method from 17 to 23 d of age (experiment 2).

2. Materials and methods

All animal care procedures were approved by the Institutional Animal Care and Use Committee of University of Hawaii.

2.1. Husbandry

Two energy balance experiments were conducted at Small Animal Facility in the Magoon Research Station of the University of Hawaii at Manoa (Honolulu, HI, USA). Day old broiler chicks (Cobb 500) were obtained from a local hatchery (Asagi Hatchery Inc., Honolulu, HI, USA) and raised on corn-soybean meal (SBM) based starter diet until day 3. In experiment 1, 160 birds were used from 4 to 10 d of age (10 pens replicate per treatment with 8 chicks/pen). Upon arrival at the research facility, the birds were weighed individually, wing tagged and distributed randomly into grower battery. In experiment 2, the same 160 birds from experiment 1 were used from 17 to 23 d of age (8 pens replicate per treatment with 5 chicks/pen). Before starting the experiment, all the birds were distributed randomly into grower battery. In both experiments, all pens had similar average BW and approximately the same numbers of males and females. Each cage was equipped with one feeder and one drinker. In experiment 1, the birds had ad libitum access to feed and water. In experiment 2, feeding was restricted to four experimental treatments. The experimental facility was a solid-sided house with temperature control. Temperature was set at 30 °C and 27 °C in experiments 1 and 2, respectively.

2.2. Macadamia nut cake and dietary treatments

The same batch of MNC was used in both experiments and was analyzed for their nutrient profile (Table 1). Macadamia nut cake was sourced from a local macadamia nut miller (Oils of Aloha, Kunia, HI, USA). The mill uses solid pressure extraction to extract oil from macadamia nut and leftover is labelled as MNC. Basal diet was same in both experiments and were formulated to meet or exceed the nutrients requirement of broilers (NRC, 1994). The experimental diets were made by adding MNC to the basal diet (Table 2). In experiment 1 (from d 4 to d 10), there were two experimental diets consisting of basal diet and addition of 60 g/kg of MNC (940 g/kg basal diet + 60 g/kg of MNC). Experiment 1 was a preliminary experiment that estimated AME_n by difference method, where AME_n of the basal diet was subtracted from the AME_n of the diet containing 60 g/kg of MNC. Birds were fed ad libitum. In experiment 2 (from d 17 to d 23), there were four experimental diets, 1) Control diet (basal diet, no addition of MNC), 2) addition of 30 g/kg of MNC (970 g/kg of basal diet + 30 g/kg of MNC), 3) addition of 60 g/kg of MNC (940 g/kg of basal diet + 60 g/kg of MNC), and 4) addition of 90 g/kg of MNC (910 g/kg of basal diet + 90 g/kg of MNC). In experiment 2, the birds were fed restricted; each of group of 8 birds were fed at 0.435 kg/day of basal diet plus the corresponding addition of MNC depending on the treatments, therefore, control groups of birds were fed with 0.400 kg/d of control diet, and the groups 2, 3, and 4 were fed with 0.448 kg/d, 0.461 and 0.475 kg/d of the experimental diets, respectively. Restricted feeding varying proportions of the intake allowed each treatment group to consume the same amount of basal diet; so, differences in AME_n consumption were due to MNC. Subsequently, the AME_n intake was regressed against feed intake with the slope representing AME_n of MNC (Adeola, 2001; Dozier et al., 2008). One advantage of using regression analysis is that the slope estimate involves multiple inclusion levels instead of estimating from 1 level. The daily feed allowance was divided into 2 equal meals that were offered at 08:00 and 17:00. In order to avoid the carry over effect of MNC inclusion in experiment 1, all birds were fed with commercial corn-SBM based starter diet during the non-experimental period (from d 12 to 16).

2.3. Measurements

Body weight of chicks was recorded at the time of entry to cages and at the end of each experiment, which will prove that dietary treatment did not limit growth. Any mortality was recorded and weighed. Birds were starved overnight the day before experimental diet feeding was started (last night of adaptation period). Total excreta (feces and urine) samples were collected three times daily for 72 h after 3-day adaptation period to estimate apparent metabolizable energy of MNC. During collection period, plastic sheet was placed in trays under the cages and the excreta on the plastic sheet was collected. Also, feed offered and feed refusal were weighed daily during 72 h of collection period. Collected samples were pooled per cage over collection period and total were weighed on a wet

Table 1
Chemical composition of the macadamia nut cake used in experiments 1 and 2 (g/kg, as-fed basis unless otherwise indicated).[a]

Item	Value
Dry matter	946.0
Total ash	33.0
Gross energy (MJ/kg)	18.8
Crude protein	176.0
Ether extract	90.1
Starch	105.0
Crude fiber	217.6
Neutral detergent fiber	500.4
Acid detergent fiber	391.0
Acid detergent lignin	151.4
Total Amino acids	
Lysine	6.6
Methionine	2.2
Threonine	4.8
Isoleucine	4.9
Valine	5.6
Tryptophan	6.3
Arginine	1.3
Leucine	15.7
Lysine	3.4
Methionine	8.8
Calcium	1.1
Total Phosphorus	3.8
Sodium	0.2
Magnesium	2.4
Potassium	8.4

[a] Analyzed in duplicate samples.

basis and stored at −20 °C immediately after collection. Homogenous excreta samples were taken by selecting multiple sub-samples out of total excreta, and 250 g of representative samples were collected in a sealable plastic bag for further analysis. On d 23, all birds were weighed and euthanized by asphyxiation using carbon dioxide.

2.4. Chemical analysis

Representative samples of MNC and experimental diets were dried in a hot-air oven at 55 °C for 72 h. Dried sample were ground using a Wiley mill (Thomas Model 2 Wiley® Mill, Thomas scientific, Swedesboro, NJ) equipped with 1 mm screen to ensure a homogenous mixture, except for starch analysis where 0.5 mm screen size was used to grind. The MNC, experimental diets and excreta samples were analyzed using Official methods of AOAC (2006) with specific procedures as follows: Dry matter (DM) of excreta samples was obtained in a two-stage drying process. In the first stage (DM1), the wet excreta were homogenized and dried at 55 °C for 48 h (method 934.01) in a forced-draft oven as sample preparation for DM. In the second stage (DM2), the dried excreta were ground through a 1-mm screen and an analytical DM (method 930.15) was determined in triplicate using approximately 2-g subsamples. The product of DM1 and DM2 gives the DM of feces. Total ash and crude fiber were determined using the methods 942.05 and 978.10, respectively. Gross energy (GE) was determined using an oxygen bomb calorimeter (Parr Isoperibol Bomb Calorimeter 6200, Parr Instrument Co., Moline, IL, USA) with benzoic acid as the calibration standard. The N content of samples was determined by dry combustion using a LECO analyzer (LECO CN-2000, Leco Corp., St. Joseph, MI, USA; method 976.05) and used to calculate crude protein (CP) content (CP = N × 6.25) with ethylenediaminetetraacetic acid as a calibration standard. Ether extract in MNC samples were determined (method 920.39) using Soxhlet apparatus and petroleum ether. Acid detergent fiber (ADF) and neutral detergent fiber (NDF) in (methods 973.18 and 2002.04, respectively) was determined using Ankom^{200} Fiber Analyzer (Ankom Technology, Macedon, NY, USA). Acid detergent lignin (ADL) was analyzed by was determined by sulphuric acid method (Robertson and Van Soest, 1981; AOAC, Official Method 973.18, A-D, 2006). Total starch content (method 996.11) was determined using a Megazyme test kit (Megazyme International, Ireland, UK). Amino acid analyses of MNC sample was done using method 982.30 E (a, b, c). Separation and quantification of amino acids (AA) in MNC was performed using a high-performance liquid chromatography system (UltiMate 3000; Thermo Scientific, Waltham, MA, USA) coupled with a fluorescence detector with precolumn derivatization, using fluoraldehyde as the reagent (Sedgwick et al., 1991). For all AA except cysteine, methionine and tryptophan, the samples were hydrolyzed with 6 mol/L HCl for 24 h at 110 °C before injection. A β-amino-*n*-butyric acid and ethanol amine mixture was used as the internal standard. The cysteine content was determined as cysteic acid, and the methionine content was determined as methionine sulfone after oxidation with performic acid before hydrolyzing with 6 mol/L HCl. The tryptophan content was analyzed accordingly (method 982.30E).

Table 2
Ingredient composition and calculated and determined analysis of the basal diet (g/kg, as-fed basis unless otherwise indicated).[a]

	Basal diet
Ingredient	
Corn	530.0
Soybean meal	370.0
Soybean oil	49.7
Limestone	14.0
Di-cal Phosphate	15.0
L-Lysine HCL (79%)	2.3
DL-Methionine (98%)	3.0
L-Threonine (98%)	2.0
Sodium chloride (39% Na)	4.0
Mineral and vitamin mix[b]	10.0
Calculated nutrient content[c]	
Dry matter	889.0
Apparent metabolizable energy (MJ/kg)	12.8
Crude protein	211.5
Total ash	
Neutral detergent fiber	87.0
Crude fiber	37.6
Total amino acids	50.2
Lysine	13.1
Methionine	6.2
Threonine	9.9
Isoleucine	8.8
Methionine + Cysteine	10.2
Valine	11.5
Tryptophan	3.1
Arginine	15.1
Cysteine	4.0
Leucine	17.8
Calcium	9.3
Total phosphorus	7.0
Sodium	1.7
Chlorine	2.8
Analyzed nutrient content[d]	
Dry matter	911.8
Gross energy (MJ/kg)	16.9
Crude protein	208.0
Total ash	56.1
Calcium	9.0
Total phosphorus	6.8

[a] The basal diet was used to produce the experimental diet as follow: control diet (basal diet, no addition of MNC), 2) addition of 30 g/kg of MNC (970 g/kg of basal diet + 30 g/kg of MNC), 3) addition of 60 g/kg of MNC (940 g/kg of basal diet + 60 g/kg of MNC), and 4) addition of 90 g/kg of MNC (910 g/kg of basal diet + 90 g/kg of MNC).

[b] Providing the following (per kg of diet): vitamin A (trans-retinyl acetate), 10,000 IU; vitamin D_3 (cholecalciferol), 3000 IU; vitamin E (all-*rac*-tocopherol-acetate), 30 mg; vitamin B_1, 2 mg; vitamin B_2, 8 mg; vitamin B_6, 4 mg; vitamin B_{12} (cyanocobalamin), 0.025 mg; vitamin K_3 (bisulphatemenadione complex), 3 mg; choline (choline chloride), 250 mg; nicotinic acid, 60 mg; pantothenic acid (D-calcium pantothenate), 15 mg; folic acid, 1.5 mg; betaine anhydrous, 80 mg; D-biotin, 0.15 mg; zinc (ZnO), 80 mg; manganese (MnO), 70 mg iron ($FeCO_3$), 60 mg; copper ($CuSO_4 \cdot 5H2O$), 8 mg; iodine (KI), 2 mg; selenium (Na_2SeO_3), 0.2 mg.

[c] According to NRC (1994).

[d] Analyzed in duplicate samples.

2.5. Calculations

Feed consumption and excreta weighted during 72 h collection period were used to calculate energy and N intake and excretion. The AME_n of experimental diets by total excreta collection was calculated by using following equation:

$$AME_n = [GEI - GEE] - [8.73 \times (NI - NE)]/FI,$$

where GEI = gross energy intake; GEE = gross energy output in the excreta; NI = N intake from the diet; NE = N output from excreta; FI = feed intake; and 8.73 = N correction factor reported from previous research (Titus, 1956).

The digestibility of the experimental diets was calculated using the following equation (Adeola, 2001).

$$\text{Digestibility, g/kg} = [(\text{feed consumed} - \text{amounts voiced in feces})/\text{feed consumed})]$$

The digestibility of the MNC was calculated using the following equation (Adeola, 2001):

$$AME_n \text{ of MNC} = [(T * T_p) - (B * B_p)]\ A_p$$

where T = coefficient of digestibility of the MNC diet, g/kg; B_p; = is the proportion, g/kg, of the component in the total diet contributed by the basal diet; A_p = is the proportion, g/kg, of the component in the total diet contributed by the test MNC and $T_p = B_p + A_p$.

2.6. Statistics analysis

Data were statistically analyzed using SAS (Version 9.2, SAS Institute Inc., Cary, NC, USA) involving a completely randomized design. Three analyses were done as follow: in experiment 1, ANOVA with treatment means separated by the least significance comparison was used. In experiment 2, treatments sums of squares for the effects of inclusion level of MNC on energy balance parameters was partitioned into linear (L) and quadratic (Q) effects using the MIXED procedure of SAS. The AME intake was regressed against feed intake to determine AME_n of MNC. Statistical significance was considered at $P < 0.05$. Observations were removed when the response criteria exceeded 2 standard deviation from the mean.

3. Results

3.1. Nutrient profile of macadamia nut cake

The representative sample of MNC was found to contain 946 g/kg of DM, 176 g/kg of CP, 90.1 g/kg of ether extract, 111 g/kg of starch, 0.066 g/kg of lysine and 0.022 g/kg of methionine. On DM basis, crude fiber, NDF, ADF, and ADL and were 230, 529, 413 and 160 g/kg, respectively. Gross energy content was found to be 18.83 MJ/kg on a DM basis.

3.2. Energy balance

The mortality was very low (1.6%) and all occurred during the first 3 days of age of broilers.

In experiment 1, the AME_n of MNC was found to be 10.09 MJ/kg in birds of age 7–10 d calculated by the difference method. Feed intake, energy excretion, AME_n, AME_n intake and the digestibilities of the basal and MNC diet were not affected ($P > 0.05$) by the inclusion of 60 g/kg of MNC (Table 3).

In experiment 2, the AME_n of MNC was found to be 10.17 MJ/kg with birds of 20–23 d of age when calculated by the regression method (Table 4). Regressing AME_n intake against feed intake (Fig. 1) resulted into the equation Y = 2,908.2x − 122.73 ($P < 0.001$; SEM of the slope = 11.7; $r^2 = 0.93$). Feed intake was restricted as such way that increased linearly ($P < 0.001$) from the basal diet to 90 g/kg of MNC diet. No feed wastage was recorded in any of the 3 days of feeding. In addition, AMEn, intake and AMEn increased linearly as the inclusion of MNC was increased ($P < 0.001$). However, the energy excretion was not affected ($P > 0.05$) by increased MNC inclusion in the diet, but tended to be significant at lineal ($P = 0.060$) and quadratic ($P = 0.065$) response.

Table 3
Energy balance of broilers fed with 60 g/kg of Macadamia nut cake (MNC) from 8 to 10 d of age in experiment 1.

Item	Control diet[c]	MNC[d]	SEM[e]	*P-value*
BW (kg)	0.344	0.338	0.003	0.287
Feed intake (kg)	0.353	0.350	0.004	0.902
Energy excretion (MJ)	1.16	1.20	0.052	0.650
AME_n[f] (MJ/kg)	15.68	15.74	0.119	0.756
AME_n, intake (MJ)	6.09	6.07	0.072	0.847
Digestibility (g/kg)	0.657	0.658	0.011	0.765
AME_n[g] of MNC (MJ/kg)	–	12.09	0.064	

[a,b]Mean values within a column with no common letters are significantly different ($P \leq 0.05$) as determined by least significant difference comparison.
[c] Control diet contained 100% basal diet.
[d] Macadamia nut cake diet contained 940 g/kg of basal diet and 60 g/kg of MNC.
[e] Values are least squares means of 10 replicate pens each pen having 8 chicks per pen with a mean BW of 0.044 kg on 1 d of age.
[f] $AME_n = [GEI - GEE] - [8.73 \times (NI - NE)]/FI$, where GEI = gross energy intake; GEE = gross energy output in the excreta; NI = nitrogen intake from the diet; NE = nitrogen output from excreta; FI = feed intake; and 8.73 = nitrogen correction factor reported from previous research (Titus, 1956).
[g] Determined by using the difference method (Adeola, 2001).

Table 4
Energy balance of broilers fed graded levels of Macadamia nut cake (MNC) from 21 to 23 d of age in experiment 2.

Item	Added% of MNC				SEM[i]	*P*-Value	
	0[e]	30[f]	60[g]	90[h]		Linear	Quadratic
23-d BW (kg)	0.776	0.802	0.787	0.827	0.011	0.353	0.933
Feed intake (kg)	0.435[d]	0.448[c]	0.461[b]	0.475[a]	0.004	0.001	0.452
Energy excretion (MJ)	1.58	1.62	1.50	1.83	0.082	0.060	0.065
AME_n, intake (MJ)	5.77[a]	5.98[b]	6.19[c]	6.24[d]	0.140	0.001	0.126
AME_n[j] (MJ/kg)	13.27[d]	13.31[c]	13.52[b]	13.60[a]	0.090	0.016	0.289

[a–d]Mean values within a column with no common letters are significantly different ($P \leq 0.05$) as determined by least significant difference comparison.
[e] Control basal diet.
[f] Macadamia nut cake diet contained 970 g/kg of basal diet and 30 g/kg of MNC.
[g] Macadamia nut cake diet contained 940 g/kg of basal diet and 60 g/kg of MNC.
[h] Macadamia nut cake diet contained 910 g/kg of basal diet and 90 g/kg of MNC.
[i] Values are least squares means of 8 replicate pens each pen having 5 chicks per pen with a mean BW of 0.515 kg at 17 d of age.
[j] $AME_n = [GEI - GEE] - [8.73 \times (NI - NE)]/FI$, where GEI = gross energy intake; GEE = gross energy output in the excreta; NI = nitrogen intake from the diet; NE = nitrogen output from excreta; FI = feed intake; and 8.73 = nitrogen correction factor reported from previous research (Titus, 1956).

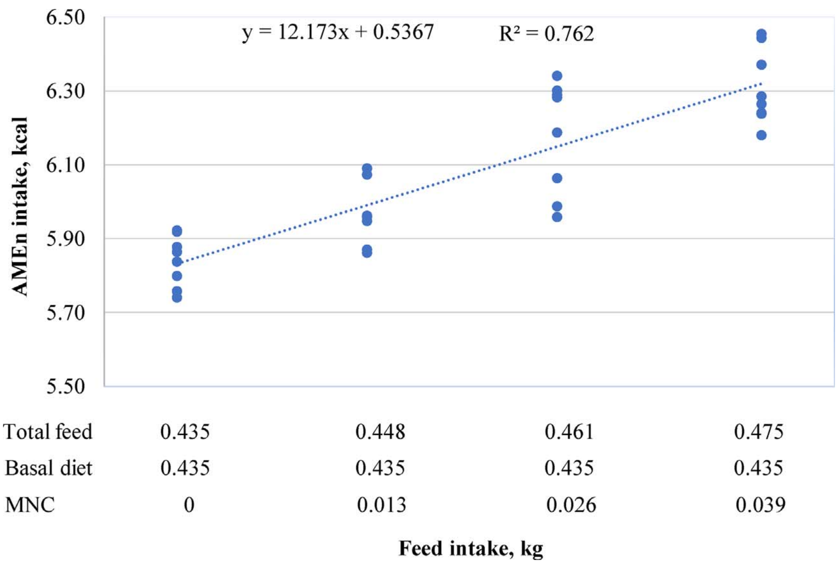

Fig. 1. Regression of AME_n intake vs. feed intake from 21 to 23 d of age in experiment 2.

4. Discussion

The agro-climatic conditions, farming system and maturity of nuts, and the oil extraction process affect the nutrient profile of oilseed based by-products like MNC. Thus, nutrient profile of MNC and their utilization in animals may vary among different sources. In this respect, the MNC used in the current experiment contained 529 g/kg of NDF, which is similar to reported by Acheampong-Boateng et al. (2008) and Skenjana (2011) having 518 g/kg and 498 g/kg of NDF, respectively. However, the NDF values reported in these researches are much higher than the NDF value (358 g/kg) reported by Tiwari and Jha (2017). The differences in NDF content among the researches might be due to quality of the original nuts, processing techniques applied and the contamination with high concentration of macadamia shell pieces. Unfortunately, no technical information about the process used to obtain the MNC by local oil processing mill is available. Moreover, GE and CP content in this experiment were 18.83 MJ/kg and 176 g/kg, respectively, both values are lower than that reported by Tiwari and Jha (2017) who obtained a GE content of 23.36 MJ/kg, and CP content of 255 g/kg. The GE content in MNC is comparable with GE corn and higher than SBM, which could be due to high residual oil content, while protein content is twice as high as corn but lower than SBM. In addition, the crude fiber content, and the presence of anti-nutritional factors like tannin and phytic acid (not considered under the scope this experiment) need to be considered before using MNC in broiler's diet. The data suggest that the nutrient content of MNC is highly affected by processing techniques applied, i.e. the extrusion process adopted by the oil producing industry. Finally, the quality of kernels also could affect the nutritive value of MNC to a large extent.

The mean AME_n content of MCN from the 2 experiments was estimated as 12.13 MJ/kg. Despite MNC contains about 500 g/kg of NDF, it's AME_n is 61% of GE. It seems that the major share of AME in MNC comes from the residual oil. In fact, the ether extract content in MNC is highly variable depending of the batch or source, for example Tiwari and Jha (2017) reported ether extract value of

MNC being 119 g/kg while in the current experiment it was 90 g/kg. Moreover, the numerical difference in AME_n value between both experiments was 0.08 MJ/kg (12.09 vs. 12.17 MJ/kg), which should be not significant because the SEM of AME_n was 15.2 and 11.7 for experiment 1 and 2, respectively. Also, the data suggest that the AME_n could be not affected by the age of the birds, however, future research should determine if AMEn of MNC of adult birds is close with the value reported herein.

The inclusion level of MNC that were studied in the current study are lower than the normally inclusion levels (> 300 g/kg) used to calculate the metabolizable energy of protein starch-protein sources by difference (Adeola, 2001). At inclusion level of 60 g/kg in the experiment 1, the energy contribution from the MNC is low and the AME_n could be underestimated. However, the experiment 1 was a preliminary trial to estimate the AME_n value. In experiment 2, the three levels chosen were based on the results obtained in a previous experiment conducted in our lab. Berrocoso et al. (2016) compared a control diet with 3 levels of MNC (50 vs. 100 and 150 g/kg) and reported that the feed intake of the pasture raised broiler chickens was negatively affected when the birds were fed with 150 g/kg of MNC. In addition, the levels of MNC (30, 60 and 90 g/kg) used herein was to adapt to commercial practice. Because of the high fiber content in MNC, the broiler industry would use a maximum inclusion level of 60–90 g/kg, hence, 30 and 60 g/kg would be within the maximum range. The 90 g/kg of MNC level was chosen to create adequate spread so an AME_n value could be determined with regression analysis.

In conclusion, AME_n of MNC was found to be 12.09 and 12.17 MJ/kg in experiment 1 and 2, respectively with an average of 12.13 MJ/kg on DM basis. Based on this study, AME_n can be assigned 60–65% of its GE. These results indicate that AME_n of MNC is comparable to conventional feedstuffs with similar nutrient profile, thus can be incorporated in broiler diets. However, as other co-products, the nutrient profile of MNC is variable which will affect the AME_n content of MNC as well. Thus, different batches of MNC should be evaluated for their nutrient composition before being used to formulate broiler diet using Macadamia nut cake. Future research should determine if AMEn of MNC of adult birds is close with the value reported herein for young birds.

Conflict of interest

None.

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