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ANIMAL SCIENCE

Growth performance, carcass traits and meat quality of lambs fed increasing level of Macadamia nut cake

MICHAEL N.S. MARCONATO, TAMIRES P. SANCHES, CAMILA M.S. CHAVES, MAURO S. BUENO, JULIANO ISSAKOWICZ, MARCIA M.H. HAGUIWARA, CLÁUDIA CRISTINA P. DE PAZ, LETÍCIA L. DOS REIS, ADIBE LUIS ABDALLA & RICARDO L.D. DA COSTA

Abstract: A total of 40 lambs were divided into four different treatments according to the inclusion level of the macadamia nut cake: C-control (0%), M1 (6.5%), M2 (12%) and M3 (20%). Feed was provided twice a day; animal weighing along with body condition scoring occurred within a 14-day interval. The lambs were slaughtered at the end of the performance test. Analysis of variance was performed through the Mixed procedure of the SAS, as well as linear and quadratic regression analysis. The groups presented differences between the treatments ($P < 0.05$) for dry matter intake (DMI), ethereal extract intake (EEI), consumption in relation to live weight percentage and feed conversion ratio (FCR). The lowest mean DMI was obtained by the animals that received the M2 and differed from the C treatment, whose average was the highest. The EEI was highest for the M3 group and the FCR was also better for this group. There was a linear effect for EEI and FCR, and quadratic for crude protein intake. There was no effect for carcass characteristics, and only initial pH had a decreasing linear effect. The macadamia nut cake was effective in promoting the performance of the animals, since there was an improvement in feed conversion.

Key words: by-products, energetic residue, sheep, sustainability.

INTRODUCTION

The production of sheep meat has strong potential for growth in Brazil, due mainly to the market for lamb, which has been gaining ground in most regions of the country. The number of head exceeds 16 million, distributed in different regions (de Castro et al. 2012). There is a lack of organization of the production chain, which in turn has a negative reflection on the quality and consumption of meat, which is still low compared to many other countries (Leite et al. 2014).

The production of lamb meat is mainly limited by the high cost of inputs, especially when it comes to feed. Therefore, it is promising to use alternative feed materials and management measures, aiming to minimize costs and maximize production (Decker et al. 2016).

Competition for grains for food, feed, and stocks for biodiesel industries will be intensified due to the expected shortage of fossil fuel for the next decades. Therefore, the use of more expensive cereals for animal feed will need to be reduced substantially. As a result, the animal protein will be less and less provided by the industrial chain of chickens, pigs and cattle and, on the other hand, will be more composed of ruminants fed with fodder and co-products of agricultural production (Leng 2014). From the consumer's point of view, there is growing concern about the sustainability of the intensification of the livestock industry and its potential damage to the environment, human health, and animal welfare. In some consumer segments, extrinsic factors (ie origin of products, general production practices, animal welfare, social and religious values, climate change, air and water pollution, and human health) appear to be important in deciding whether purchase (Montossi et al. 2013).

The use of material from nut processing in sheep feed can help boost the nutritional value of lamb meat and benefit production by using a highly energetic residue (Acheampong-Boateng et al. 2017) that would otherwise be discarded in the environment. Macadamia nuts are considered the noblest nut in the world due to their delicate flavor, crisp texture and color (Penoni et al. 2011). Macadamia was introduced in Brazil in 1931, with the importation of some plants of American origin (Pimentel 2007). However, it was expanded in the national territory after actions of the production and research sectors from the 1970s. Agroclimatic zoning indicates large areas with favorable conditions for the cultivation of macadamia nuts in Brazil, where almost the entire state of São Paulo, Rio de Janeiro. January, Espírito Santo, southern Minas Gerais, eastern Mato Grosso do Sul and western Paraná are inserted (Moura et al. 2014).

Whole almond is the main commercial product, which can be eaten raw, roasted or fried, salted, caramelized, chocolate covered, fine candies and also as a cover for confectionery and ice cream. Almonds broken during processing or of inferior quality are used for extraction of excellent quality oil, mainly used in the pharmaceutical industry and in the manufacture of cosmetics, be used as an ingredient in processed products such as cakes and cookies (Neto & Nogueira 2010). The oil extraction residue has potential for animal nutrition, as will be investigated in the present project, which the objective was to determine the effects of dietary inclusion of Macadamia coproduct on growth performance, carcass traits and meat quality of lambs.

MATERIALS AND METHODS

Animal care

The experiment was registered with the Ethics Committee on Animal Experimentation (CEUA/IZ—n°. 221/2015); This committee is institutional, but it is governed and inspected by the National Council for the Control of Animal Experimentation, under the responsibility of the Ministry of Science, Technology and Innovation, at the national level.

Animals, diet, feeding and traits measured

The experiment was carried out in the sheep confinement sector of the Institute of Animal Science, located in the city of Nova Odessa, São Paulo state, Brazil, with geographical coordinates of 22° 46' 39" S latitude and 47° 17' 45" W longitude and altitude of 570 m.

Forty male crossbred lambs (Dorper x Santa Inês) were used, with initial ages of approximately 90 days and average initial body weight (BW) of 18±3.7 kg. The animals were separated into randomized blocks according to initial weight (kg). The treatments were formulated according to the different levels of Macadamia nut cake (Macadamia co-product) added to the isoprotein concentrate: 0% inclusion in the control (C) group; 6.5% in M1; 12% in M2; and 20% in M3. All animals were treated for endoparasites (Ripercol® L – 150F, Zoetis) and underwent a 5-day adaptation period to the control diet and, after, another 10 days adaptation to the treatment diet (Farenzena et al. 2017).

Feed was provided twice a day, at 8:00 a.m. and 4:00 p.m., consisting of 70% concentrated feed with 30% roughage, composed of Tifton 85 hay (*Cynodon dactylon*) with 93% DM, 13.4% CP, 1.4% EE, 74.3% NDF and 6.9 ASH. The concentrate mixture contained milled corn, soybean meal, calcitic limestone, mineral mix for sheep and sodium chloride. The consumption was adjusted daily in the morning, before the first feeding, leaving a quantity of leftovers varying between 10% - 20%. The nutritional composition of the ingredients and diets is shown in Table I and Table II.

Animal weighing and body condition scoring (Sanudo & Sierra 1986), and ranked on a scale (1= thin; 5= obese) with half-point intervals (Pugh 2004) were performed every 14 days during the morning before feeding. Feed samples were collected weekly, both from the new feed and leftovers from each trough, for subsequent chemical analysis.

Table I. **Chemical composition of the ingredients used in the experimental diets.**

	Milled corn	Soybean	Macadamia nut cake
DM (%)	87.36	89.51	97.72
CP (%)	9.63	52.95	9.86
CF (%)	1.79	5.50	4.96
EE (%)	2.81	1.62	60.45
MM (%)	1.00	6.98	1.77
NNE (%)	84.77	32.90	22.97
NDF (%)	8.97	14.58	4.18
TDN (%)	81,34	85.85	165.81

DM = dry matter; CP = crude protein; CF= crude fibre; EE = ethereal extract; MM = mineral matter; NNE = non-nitrogenous extractives; NDF = neutral detergent fiber and TDN = total digestible nutrients (% = 40.2625 + 0.1969 PB + 0.4028 NNE + 1.903 EE - 0.1379 CF). Values expressed as % of DM. Inclusion level of the macadamia coproduct in the concentrate: C-control (0%), M1- (6.5%), M2- (12%) and M3- (20%).

For the performance test, the feed samples were weighed and placed in an air circulation oven at 65 °C for 72 hours until constant weight. After cooling to room temperature, they were weighed again and ground in a Wiley mill equipped with a 2 mm mesh sieve. The contents of dry matter (DM), crude protein (CP), ethereal extract (EE), mineral matter (MM), neutral detergent fiber (NDF), acid detergent fiber (ADF), non-nitrogenous extractives (NNE) - according to AOAC (1995), hemicellulose (Hemic% = NDF

Table II. **Formulation and nutritional composition of the concentrates, according to the level of inclusion of the Macadamia nut cake.**

	C	M1	M2	M3
Milled corn (%)	69	62.5	57	49
Soybean meal (%)	27	27	27	27
Macadâmia(%)	0	6.5	12	20
Calcitic limestone (%)	1.5	1.5	1.5	1.5
Mineral mix(%)	1.5	1.5	1.5	1.5
Sodium chloride(%)	1	1	1	1
DM (%)	89,27	89,32	89,95	90,45
CP (%)	18,99	18,02	18,95	19,48
CF (%)	3.07	3.85	2.93	3.26
EE (%)	1,49	3,82	6,28	8,68
MM (%)	7,16	6,22	6,30	6,68
NNE (%)	60,81	59,84	57,01	53,46
NDF (%)	31,42	32,82	31,52	32,66
TDN (%)	75,93	77,49	80,70	83,15

DM = dry matter; CP = crude protein; CF = crude fibre; EE = ethereal extract; MM = mineral matter; NNE = non-nitrogenous extractives; NDF = neutral detergent fiber and TDN = total digestible nutrients (% = 40.2625 + 0.1969 PB + 0.4028 NNE + 1.903 EE - 0.1379 CF). Values expressed as % of DM. Inclusion level of the macadamia nut cake in the concentrate: C-control (0%), M1- (6.5%), M2- (12%) and M3- (20%).

- ADF), and total digestible nutrients (TDN): TDN% = 40.2625 + 0.1969 CP + 0.4028 NNE + 1.903 EE - 0.1369 CF for energy foods, according to Kearl (1982), were determined.

Intake of dry matter (DMI), ethereal extract intake (EEI) and crude protein intake (CPI) were calculated according to the difference between what was supplied and what was left over. The animal weight and nutrient intake data were used to determine: average daily weight gain (ADG = total gain ÷ n days of experiment), consumption as percentage of live weight (LW% = (DMI * 100) ÷ live weight], and feed conversion ratio (FCR = DMI ÷ DWADG). We also calculated the Kleiber rate (KR), expressed as the ratio between mean daily weight gain and metabolic live weight (KR = ADG ÷ $LW^{0.75}$) and the relative growth rate, which takes into account the initial body weight and the final body weight in the experimental period [RGR = 100 * (log FBW-log IBW) ÷ test days] (Fitzhugh & Taylor 1971).

At the end of the experiment, the lambs were fasted for 16 hours before being slaughtered, after weighing about 1 hour beforehand for the measurement of hot carcass yield (HCY) and cold carcass yield (CCY).

The animals were slaughtered at the Meat Technology Center of the Food Technology Institute (ITAL), in accordance with the rules described in the Regulation of Industrial and Sanitary Inspection of Products of Animal Origin (RIISPOA), following all animal management welfare procedures. At the time of slaughter, the animals were numbed by stunning by a penetrating dart fired into in the frontal region of the head. Then blood was drawn through the carotid and jugular veins. After skinning and evisceration, the head (section at the atlanto-occipital joint) and the hooves (section on the carpus and tarsometatarsal joints) were removed and the weight of the hot carcass (HCW) was recorded. pH and temperature were also measured at just after slaughter (0h) with a portable pH meter (Quimis model Q400HM) with temperature sensor.

The carcasses were then taken to the refrigeration chamber where they remained for a period of 24 hours at a temperature of 4 °C. On the following day, the carcasses were again weighed to obtain cold carcass weight (CCW), temperature and pH 24 h post-slaughter, as well as evaluation of carcass conformation, which expresses the development of muscular masses. Carcass of value 1.0 as the most concave and value of 5.0 is the most convex. Convex carcasses are preferable since they have a higher muscle: bone ratio. The finishing fat was measured to subjectively evaluate the fat cover of the carcass through a visual score ranging from 1.0 to 5.0 (1.0 = carcass with a low finish and 5.0 = carcass with high finish). The hot and cold carcass yields were calculated according to the following equations: HCY (%) = (HCW ÷ Fasting live weight) * 100 and CCY (%) = (CCW÷ Fasting live weight). The loss due to cooling was also calculated: LC (%) = [((HCW-CCW) ÷ HCW) * 100] (Pérez & Carvalho 2007).

The *Longissimus lumborum* muscle was cut transversally between the last thoracic vertebra and the first lumbar, in the cut known as loin. The cross-sectional area of the muscle region was measured, along with the length and depth. Afterward, the loin eye area (cm^2) for each sample was determined from the maximum medial distance (A) and maximum back-ventral distance (B), according to the following equation: LEA (cm^2) = (A / 2 x B / 2) x 3.1416 (Cezar & Sousa 2007). In this same muscle, subcutaneous fat thickness (SFT) was measured with a digital caliper. Qualitative characteristics were also determined, such as luminosity: L* (reflectance or transmittance), a* (red intensity) and b* (yellow intensity) using a colorimeter (Minolta model CM-600d), according to the CIELAB system (MacDougall 1994). Samples of the longissimus lumborum were frozen for further analysis of the centesimal composition, according to the method described by Campos et al. (2004).

The samples were weighed in an aluminum container and baked at a temperature of 180 °C. A thermoresistor thermometer with 5 angular rods was inserted in each sample and the temperature of the samples was approximately 72 °C. After cooling to room temperature, the meat samples were again weighed to determine the amount of water lost during cooking and the amount of water evaporated during cooking, expressed as a percentage (g/100g) (Osório et al. 1998).

The analysis of shear forces was carried out approximately 2.5 cm perpendicular to the muscle fibers. With the help of a cylindrical mold, three cylinders of each piece of the muscle were removed and placed in a texturometer (TA-XT 2i), coupled to a Warner Bratzler blade (1 mm thickness). The equipment was calibrated to a standard weight of 5 kg. The rate of descent of the device was 200 mm / min (AMSA 1995). The final value was taken as the mean of 12 readings per sample, expressed in kilograms of force (kgf).

Statistical analysis

For statistical analysis, a completely randomized block design was used, according to the initial weight (kg) of the lambs, with four treatments and 10 replicates per treatment. The sex effect of the animals was tested, but there was no significant interaction for these parameters. Statistical analyses were performed using the MIXED procedure (SAS, Inst., Inc, Cary, NC, USA). The means of the treatments were compared by the Tukey test at 5% probability. The interactions among the treatments were considered for the variables of performance, carcass quality and meat of each experimental unit. The mathematical model used is represented by the following equation: $y_{ij} = \mu + \tau_i + \varepsilon_{ij}$, where: y_{ij} = dependent variable; μ = general mean; τ_i = effect of diet, and ε_{ij} = experimental residual error. The regression analysis was performed with the PROC GLM procedure of the SAS 9.4 program (SAS 2009), according to the mathematical model represented by: $y_{ij} = \beta_0 + \beta_1 X_i + \beta_2 X_i^2 + \beta_3 X_i^3 + a_j + \varepsilon_{ij}$, where: y_{ij} = dependent variable; β's = regression coefficients; X_i = independent variables; a_j = regression deviations and ε_{ij} = residual error, considering a 5% level of significance. Regression equations are demonstrated in the table footers when significant.

RESULTS

The average daily weight gain (ADG), body condition score (BCS), dry matter intake (DMI), crude protein intake (CPI), ether extract consumption (EEI), relative growth rate (RGR), feed conversion (FC), intake of dry matter in percentage of live weight (LW%) and Kleiber rate (KR) are given in Table III. The mean of the M2 treatment was significantly ($P < 0.05$) lower than the C treatment for DMI, although in the regression analysis there was no difference ($P > 0.05$). For LW%, there was a difference ($P < 0.05$) between the means of treatments M1 and M2 with respect to treatment C. The FCR showed a linear decrease ($P < 0.05$) with the increased inclusion of the macadamia nut cake. The intake of ethereal extract (EEI) presented a quadratic increase ($P < 0.05$). No differences were observed between treatments ($P > 0.05$) for CPI, but the values had quadratic behavior ($P < 0.05$) in the regression analysis, the lowest being for the M1 treatment (Table III).

In relation to the carcass characteristics, only the initial pH presented a linear decrease ($P < 0.05$), as shown in Table IV. Among the physical and chemical characteristics of the

Table III. Performance and feed efficiency of lambs fed levels of macadamia by-product.

	C	M1	M2	M3	SEM	Y
ADG (kg)	0,195	0,193	0,185	0,210	0,02	NS
BCS (1-5)	3,42	3,46	3,29	3,34	0,24	NS
DMI (kg)	1,112[a]	0,882[ab]	0,845[b]	0,899[ab]	0,07	NS
CPI (kgMS)	0,208	0,160	0,165	0,183	0,01	*1
EEI (kgMS)	0,046[a]	0,043[a]	0,055[a]	0,091[b]	0,01	*2
FCR	5,94[a]	4,95[ab]	5,07[ab]	4,24[b]	0,36	*3
LW (%)	4,12 [a]	3,55[b]	3,52 [b]	3,65[ab]	0,13	NS
RGR	0,342	0,328	0,319	0,342	0,03	NS
KR	0,016	0,016	0,016	0,017	0,001	NS

Diets: C = control diet without inclusion of coproduct; M1 = diet with 6.5% inclusion of coproduct; M2 = diet with 12% inclusion of coproduct; M3 = diet with 20% inclusion of coproduct. Parameters: LW = live weight; ADG = mean daily weight gain; BCS = body condition score; DMI = dry matter intake; CPI = crude protein intake corrected for dry matter; EEI = intake of ethereal extract corrected for dry matter; FCR = feed conversion ratio; LW%= intake of dry matter in percentage of live weight; RGR = relative growth rate; KR = Kleiber rate; NS = not significant. Different letters in the same row differ significantly from each other by the Tukey test at 5% probability. Y = regression equation (P <0.05):
Y^1= 0.2097-0.0610x+0.0176x^2
Y^2= 0.0438-0.0092x+0.0086x^2
Y^3=5.8602-0.5407x

meat that were analyzed, only the intensity of red (a *) and the water content were significant (P <0.05), increasing for the first and decreasing for the second, according to the increase of the coproduct inclusion (Table V).

DISCUSSION

In the control treatment (C) the animals consumed more than the treatment with 12% Macadamia nut cake (M2). Satiety in high energy density diets occurs through chemostatic and non-physiostatic mechanisms, such as in high NDF diets. Animals with greater energy intake, mainly through fat, since one of the precursors of propionate is glycerol, are able to concentrate higher levels of propionate in the blood, which acts as a chemical signal of satiation. Thus, animals do not need to ingest high amounts of food to satisfy themselves, leading to a decrease in dry matter (DM) consumption (Baile 1971, Benson et al. 2002).

There were differences between the means of the treatments (P> 0.05) in the ethereal extract intake (EEI) and quadratic behavior (P <0.05) in the regression analysis. The total fat content in ruminant diets is limited, since there are reports of decreased consumption at levels that exceed 6% ethereal extract of the total diet (Palmquist & Mattos 2006, Palmquist & Jenkins 1980). The treatment with the highest content of Macadamia nut cake (M3) presented higher mean EEI, although it did not affect DMI. The highest inclusion of coproduct in the diet, although increasing the ethereal extract content, may not have had a direct influence on the ruminal fermentation parameters. Oil can inhibit the growth of cellulolytic microorganisms and favor the development of amylolytic bacteria (Santos et al. 2014), while improving feed conversion and protein efficiency by increasing the metabolizable energy content of the diet (Fernandes et al. 2011).

In the present study, feed conversion (FCR) improved linearly (P <0.05) with inclusion of the coproduct. Animals receiving the highest

Table IV. **Carcass characteristics of lambs fed with macadamia by-product.**

	C	M1	M2	M3	SEM	Y
HCW (kg)	18,37	17,05	15,85	18,10	1,59	NS
HCY (%)	54,32	49,63	49,51	51,35	1,73	NS
CCW (kg)	18,61	17,15	15,99	17,77	1,68	NS
CCY (%)	53,24	48,70	48,30	49,36	1,76	NS
LC %	1,99	1,78	2,44	3,84	0,90	NS
CCI(kg/cm²)	0,29	0,27	0,25	0,27	0,02	NS
pH I	6,97	6,85	6,92	6,79	0,06	*
pH F	6,21	6,09	6,10	6,10	0,07	NS
TI (°C)	29,51	30,05	30,37	29,59	0,50	NS
TF (°C)	10,39	10,99	10,90	10,45	0,36	NS
CONF (1-5)	3,52	3,47	3,16	3,66	0,19	NS
FC (1-5)	3,08	3,10	2,75	3,31	0,19	NS
IL (cm)	62,00	62,30	60,21	64,53	2,36	NS
TP (cm)	68,18	68,17	66,61	68,81	1,71	NS
HC(cm)	61,14	58,78	57,76	60,65	1,50	NS
LL (cm)	23,89	23,80	24,40	22,89	0,65	NS
LC (cm)	41,62	39,54	39,04	41,05	1,12	NS
LEA (cm²)	15,36	15,46	15,45	15,80	1,22	NS
SFT (mm)	2,76	2,49	1,90	2,74	0,41	NS

Diets: C = control diet without inclusion of coproduct; M1 = diet with 6.5% inclusion of coproduct; M2 = diet with 12% inclusion of coproduct; M3 = diet with 20% inclusion of coproduct; HCW = hot carcass weight; HCY = hot carcass yield; CCW = cold carcass weight; CCY = cold carcass yield; LC % = percentage of loss due to cooling; CCI = carcass compactness index; pH I = pH initial; pH F = pH final; TI = temperature inicial; TF = temperature final; CONF = conformation; FC = fat cover; IL = internal length; TP = thoracic perimeter; HC = hip circumference; LL = leg length; LC = leg circumference; LEA = loin eye area; SFT = subcutaneous fat thickness; NS = not significant. The averages were compared by the Tukey test at 5% probability. Y = regression equation (P<0.05). Y*=6.9738-0.050x

content (M3) needed to eat less food to have the same average daily weight gain (ADG) as the animals of the other treatments. This measure comprises the amount of dry matter ingested to produce one kilo of body weight (Oliveira 2013). The variable presented a decrease of 30% with the use of 20% Macadamia nut cake in the concentrate. The high energy intake in the diet combined with the large proportion of concentrate improves the FCR of animals (Nobre et al. 2016, Medeiros et al. 2007).

The percentage consumption of live weight (LW%) had the highest value of 4.12 ± 0.12% (P <0.05), which was observed for treatment C, above that recommended by NRC (2007), which is 3.50%. However, the means of the M1 and M2 treatments were 3.55% and 3.52%, respectively, which may be related to the higher intake of energy in the diet, which decreases consumption. However, no difference (P> 0.05) was observed between treatments C and M3, whose mean was 3.65%, which also obtained a similar weight gain between the treatments, making the use of the by-product efficient according to the measures.

Relative growth rate (RGR) and Kleiber rate (KR) were also not influenced (P> 0.05) by the inclusion of Macadamia nut cake in the diet. These variables are correlated with the weight

Table V. Physical and chemical characteristics of meat from lambs fed with macadamia by-product.

	C	M1	M2	M3	SEM	Y
LC (%)	16,66	18,41	16,41	20,57	1,47	NS
SF (kgf)	2,56	2,12	2,40	2,34	0,27	NS
L*	38,39	38,70	37,99	38,88	0,91	NS
a*	7,66	8,01	13,61	14,36	3,03	*1
b*	9,18	9,14	12,96	9,11	1,57	NS
Water (%)	76,83	76,24	75,89	75,77	0,34	*2
EE (%)	4,17	4,31	4,35	4,51	0,26	NS
CP (%)	17,86	18,28	18,60	18,52	0,35	NS
MM (%)	1,06	1,09	1,08	1,11	0,02	NS

Diets: C = control diet without inclusion of coproduct; M1 = diet with 6.5% inclusion of coproduct; M2 = diet with 12% inclusion of coproduct; M3 = diet with 20% inclusion of coproduct; LC% = cooking losses; SF = shear force; L* = brightness; a* = intensity of red; b* = intensity of yellow; EE = ethereal extract; MM = mineral matter; CP = crude protein. The averages were compared by the Tukey test at the 5% level. Y = regression equation (P<0.05).
Y^1=9.7673+2.6122x
Y^2=77.1543-0.3330x

gain of the animals, and this also showed no difference among the treatments.

No differences (P> 0.05) were found between the means of the variables for the carcass characteristics, which corroborates results found in the literature, such as Morgado et al. (2013), who evaluated high levels of ethereal extract in the diet of lambs from different sources of carbohydrates, such as corn and citrus pulp, associated with sunflower oil. Their results showed no significant effect on the carcass characteristics. From an economic standpoint, carcass quality depends on the relation between live weight and age at slaughter, with the aim being to obtain animals that reach higher weights in a shorter time. Thus, animals that present lower performance rates, such as average daily weight gain or slaughter weight, will have negative results reported for carcass yields (Souza 2014).

The final pH results showed a linear decrease (P <0.05) with increase of the nut cake content. The values obtained were below the recommended range, which is between 7.0 and 7.3. The final pH, found for the carcasses involved in the four treatments was high, above 6.0 (Cezar & Sousa 2007), according to whom the normal value is close to 5.4, considering the isoelectric point of muscle proteins. However, it is common to find values above 6.0 for end pH, since several factors are related to the drop in pH, one of the main being the decrease of muscle glycogen stores, which can be depleted due to stress, prolonged fasting and long waiting time. In this case, glycogen is consumed when it should be used to form lactic acid (Silva Sobrinho et al. 2005).

No effect of treatments (P> 0.05) was found for carcass morphometric measurements. These results corroborate Silva et al. (2015), who tested levels of up to 45% sunflower cake in the dry matter for confined Santa Inês crossbred lambs, did not find any influence on the carcass morphometric measurements.

Among the physical characteristics of the meat, only the intensity of red (a*) presented difference between the treatments. The averages for this characteristic had increasing linear behavior (P <0.05) with rising level of Macadamia nut cake in the diet. The corn used in the concentrated mixture was replaced by the coproduct as the inclusion occurred. Corn is rich in carotenoids (Senete et al. 2011), a type of pigment that promotes the yellowish coloration of fat (Dunne et al. 2009). Consequently, the reduction of red meat intensity caused by increased pallor occurs. In this case, the higher proportion of corn ingested by the animals belonging to the groups with lower levels of inclusion may have affected the color of the meat.

No differences were found between the means (P> 0.05) for the centesimal composition of the *Longissimus lumborum* muscle samples. However, there was decreasing behavior (P <0.05) of moisture content as the level of coproduct increased.

According to Bezerra et al. (2012), the chemical composition of sheep meat is typically 25% DM, 19% CP, 4% EE and 1.1% MM. The averages obtained in this study are close to those values. Among the analyzed variables, only the moisture content presented a significant result (P <0.05): as the coproduct content in the diet increased, there was a decrease in the moisture content.

CONCLUSIONS

The inclusion of increasing levels of Macadamia nut cake in the diet of lambs does not alter the weight gain, but it decreases the dry matter intake, and therefore improves feed conversion. Carcass and meat characteristics are little affected by the inclusion of the Macadamia nut cake in the diet. There was a decrease in the water content and an increase in the red color intensity in the meat with higher levels of inclusion.

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MICHAEL N.S. MARCONATO[1]
https://orcid.org/0000-0002-2953-1660

TAMIRES P. SANCHES[1]
https://orcid.org/0000-0003-2232-8050

CAMILA M.S. CHAVES[2]
https://orcid.org/0000-0003-4451-7506

MAURO S. BUENO[1]
https://orcid.org/0000-0003-0733-8605

JULIANO ISSAKOWICZ[3]
https://orcid.org/0000-0001-8541-9609

MARCIA M.H. HAGUIWARA[4]
https://orcid.org/0000-0002-0465-4779

CLÁUDIA CRISTINA P. DE PAZ[5]
https://orcid.org/0000-0002-7267-4552

LETÍCIA L. DOS REIS[1]
https://orcid.org/0000-0001-9198-6116

ADIBE LUIS ABDALLA[2]
https://orcid.org/0000-0002-5440-9974

RICARDO L.D. DA COSTA[1]
https://orcid.org/0000-0001-8888-6915

[1]Centro de Pesquisa em Zootecnia Diversificada, Instituto de Zootecnia (IZ), Rua Heitor Penteado, 56, 13380-011 Nova Odessa, SP, Brazil

[2]Laboratório de Nutrição Animal (LANA), Centro de Energia Nuclear na Agricultura (CENA), Universidade de São Paulo (USP), Av. Centenário, 303, 13416-000 Piracicaba, SP, Brazil

[3]Centro Estadual de Educação Profissional Olegário Macedo (CEEP Olegário Macedo), Av. Marly Rolim, s/n, Vila Rio Branco, 84172-340 Castro, PR, Brazil

[4]Centro de Tecnologia de Carne, Instituto de Tecnologia de Alimentos (ITAL), Av. Brasil, 2880, 13070-178 Campinas, SP, Brazil

[5]Centro de Bovinos de Corte, Instituto de Zootecnia (IZ), Rodovia Carlos Tonanni, km 94, 14160-900 Sertãozinho, SP, Brazil

Correspondence to: **Ricardo Lopes Dias da Costa**
E-mail: rldcosta@sp.gov.br

Author contributions

Michael Nunes Simão Marconato: collected the data and wrote the manuscript. Tamires Pinheiro Sanches, Camila de Miranda e Silva Chaves and Letícia Liepkaln dos Reis: collected the data. Mauro Sartori Bueno: reviewed the manuscript. Juliano Issakowicz: collected the data and critical reading of the manuscript. Marcia Mayumi Harada Haguiwara: conducted laboratory analysis. Cláudia Cristina Paro de Paz: statistical analysis and reviewed the manuscript. Adibe Luis Abdalla: conducted laboratory analysis and critical reading of the manuscript. Ricardo Lopes Dias da Costa: conception of the study; administered the project and reviewed the manuscript. Corresponding author.