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# Performance, nutrient digestibility, and quantitative carcass traits of lambs fed sunflower seeds and vitamin E

# Desempenho, digestibilidade dos nutrientes e características quantitativas da carcaça de cordeiros alimentados com grãos de girassol e vitamina E

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## Abstract

The aim of this study was to evaluate performance, nutrient digestibility, and carcass quantitative traits of lambs fed diets with and without sunflower seeds and vitamin E. Thirty-two uncastrated lambs at approximately 60 days of age, with 15 ± 0.2 kg, were housed in individual stalls and slaughtered at 32.0 ± 0.2 kg body weight. Treatments consisted of the following four diets: C = sugarcane + concentrate; CS = sugarcane + concentrate with sunflower seeds; CE = sugarcane + concentrate with 1,000 mg vitamin E $kg^{-1}$ diet dry matter (DM); and CSE = sugarcane + concentrate with sunflower seeds and 1,000 mg vitamin E $kg^{-1}$ diet DM. The experimental design was completely randomized, in a 2 × 2 factorial arrangement (with and without sunflower seeds and with or without vitamin E, on the diet DM basis), and means were compared by Tukey's test at 5% significance level. Consumption of vitamin E intake by the lambs provided (P<0.05) the highest ether extract intake (20.91 g $day^{-1}$) and consequently the highest (P<0.05) digestibility of this nutrient (85.34%); however, it reduced (P<0.05) the intakes of total carbohydrates (394.81 g $day^{-1}$) and non-fibrous carbohydrates (242.47 g $day^{-1}$) as a direct consequence of the diet composition. Inclusion of sunflower seeds and vitamin E in the lamb diets did not influence (P>0.05) carcass morphological or quantitative measurements. Sunflower seeds and vitamin E showed to be satisfactory alternatives for inclusion in the concentrate for feedlot lambs, providing good performance and quality carcasses.

**Key words:** Antioxidant. Commercial cuts. Oilseeds. Sheep.

## Resumo

O objetivo deste trabalho foi avaliar o desempenho, a digestibilidade dos nutrientes e as características quantitativas da carcaça de cordeiros submetidos a dietas contendo ou não grãos de girassol e vitamina

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E. Foram utilizados 32 cordeiros machos não castrados com aproximadamente 60 dias de idade e 15 ± 0,2 kg, alojados em baias individuais e abatidos aos 32,0 ± 0,2 kg de peso corporal. Os tratamentos foram compostos por quatro rações: C- cana-de-açúcar + concentrado; CG- cana-de-açúcar + concentrado com grãos de girassol; CE- cana-de-açúcar + concentrado com 1000 mg vitamina E $kg^{-1}$ de matéria seca (MS) da ração e CGE- cana-de-açúcar + concentrado com grãos de girassol e 1000 mg vitamina E $kg^{-1}$ de MS da ração. O delineamento experimental foi o inteiramente casualizado em esquema fatorial 2 x 2 (com ou sem grãos de girassol e com ou sem vitamina E na base da MS da ração) e as médias comparadas pelo teste de Tukey a 5% de significância. O consumo de vitamina E pelos cordeiros melhorou o ganho médio diário de peso (0,241 kg). A inclusão dos grãos de girassol proporcionou ($P<0,05$) maior consumo de extrato etéreo (20,91 g $dia^{-1}$) e consequentemente maior ($P<0,05$) digestibilidade desse nutriente (85,34%), no entanto reduziu ($P<0,05$) os consumos de carboidratos totais (394,81 g $dia^{-1}$) e não fibrosos (242,47 g $dia^{-1}$) como consequência direta da composição da ração. A inclusão de grão de girassol e vitamina E na dieta dos cordeiros não influenciou ($P>0,05$) nas medidas morfológicas e quantitativas da carcaça. Grãos de girassol e vitamina E mostraram-se fontes alternativas satisfatórias para inclusão no concentrado para cordeiros confinados, proporcionando bom desempenho e carcaças com boa qualidade.

**Palavras-chave:** Antioxidante. Cortes comerciais. Grãos de oleaginosas. Ovinos.

## Introduction

In intensive sheep meat production systems, aspects such as nutrition and dietary management are among the major factors responsible for increased productivity. The supply of diets of better quality reduces the finishing time for animals to reach slaughter weight, allowing the production of early lambs, with adequate fat cover, and thus meeting the consumer market demands (OLIVEIRA et al., 2016; SANTELLO et al., 2006). Because this production system is rather costly due to the high costs of inputs, the use of alternative ingredients in the diet, without impairing animal performance, is of great value.

Sugarcane is a forage plant commonly found on rural properties, especially in São Paulo state, that has been noteworthy for its lower production costs compared with other roughages, e.g., hay and corn silage (GALAN; NUSSIO, 2000). However, diets containing sugarcane require corrections in their protein and mineral contents, and a way to nutritionally complement these diets is by including oilseeds in their formulation (MORENO et al., 2010).

Oilseeds are the most widely used lipid sources in animal nutrition, usually replacing rapidly fermentable carbohydrates, providing high energy density and viability to rumen fermentation and fiber digestion (TEIXEIRA; BORGES, 2005). However, oilseeds, such as sunflower seeds, may change the composition of the meat fatty acids, the unsaturated fatty acid content, and consequently increase the requirement of antioxidants like vitamin E for the preservation of meat products (DEMIREL et al., 2006; OLIVEIRA et al., 2011).

With liposoluble characteristics, the vitamin E accumulated in cell membranes protects the polyunsaturated fatty acids and other vulnerable components of cells from oxidative damage (BERCHIELLI et al., 2011). Their ingestion in the form of foods or supplements is also related to prevention of diseases, stimulation of the immune system, and modulation of aging-associated degenerative processes (BRIGELIUS-FLOHÉ et al., 2002).

The aim of this study was thus to evaluate animal performance, nutrient digestibility, and carcass quantitative traits of feedlot-finished lambs fed diets containing sugarcane as the roughage, associated with inclusion or lack of sunflower and vitamin E in the concentrate.

## Material and Methods

This study complied with the principles of ethics in animal experimentation adopted by the Brazilian College of Animal Experimentation (*Colégio Brasileiro de Experimentação Animal*, COBEA), and was approved by the Committee for Ethics in Animal Use (*Comissão de Ética no Uso de Animais*, CEUA) of the Faculty of Agricultural and Veterinary Sciences (*Faculdade de Ciências Agrárias e Veterinárias*, FCAV – Unesp) under case no. 007670-09.

The experiment was conducted at the Faculty of Agricultural and Veterinary Sciences (*Faculdade de Ciências Agrárias e Veterinárias*, FCAV – Unesp), on Jaboticabal Campus, SP, Brazil (21º15'22" S and 48º18'58" W, 595 m altitude). Thirty-two newly weaned uncastrated male Ile de France lambs at approximately 60 days of age, with 15.0 ± 0.2 kg body weight (BW), were housed in individual stalls (covered shed) measuring approximately 1.0 $m^2$, with suspended slatted floor and equipped with feeder and drinker. At the onset of the experiment, lambs were identified, dewormed, vaccinated against clostridioses, and distributed at random into the following treatments: C = sugarcane + concentrate; CS = sugarcane + concentrate with sunflower seeds; CE = sugarcane + concentrate with 1,000 mg vitamin E $kg^{-1}$ diet dry matter (DM); and CSE = sugarcane + concentrate with sunflower seeds and 1,000 mg vitamin E $kg^{-1}$ diet DM. The amount of 1,000 mg vitamin E (α-tocopherol acetate) was used per kg of diet DM, because, according to a study conducted by Lopez-Bote et al. (2001), this was the amount of vitamin that provided the best result.

The sugarcane, of variety IAC 86-2480, belonged to the experimental canebrake of FCAV and was harvested manually with a machete (on alternate days) and chopped (to 1 cm particles) in a stationary shredding machine, immediately before being supplied to animals. The concentrate was composed of ground corn, soybean meal, urea, sodium chloride, calcitic limestone, dicalcium phosphate, and a mineral supplement. The roughage:concentrate ratio was 50:50, composing diets with similar protein (23.0%) and energy (3.0 Mcal metabolizable energy $kg^{-1}$ DM) contents. Experimental diets were formulated to meet the requirements of weaned lambs recommended by NRC (2007) for an average weight gain of 250 g $day^{-1}$ (Table 1).

Diets were supplied daily at 08h00 and 17h00, so as to allow 10% as leftovers (fresh matter); the weights of feed supplied and leftovers were recorded to estimate the dry matter intake (DMI). Lambs were weighed weekly to monitor and determine their average daily weight gain (ADG) and feed conversion (FC), obtained as the ratio between DMI (kg $day^{-1}$) and the average weight gain (kg). The period during which the animals were fed the diets varied with the feedlot period, which was 75 days, on average.

Samples of diets supplied and 10% of the leftovers from each animal were harvested weekly and stored in a freezer at –18 ºC, with composite samples formed at the end of the experiment. These were pre-dried in a forced-air oven at 55 ±5 ºC, for 72 h, and later ground in a mill with knives and 1-mm sieve for determination of the DM, organic matter (OM), mineral matter (MM), crude protein (CP), and ether extract (EE), according to methods described by Silva and Queiroz (2006).

Concentrations of lignin, neutral detergent fiber corrected for ash and protein (NDFap), and acid detergent fiber (ADF) were determined according to Van Soest and Wine (1967). Total carbohydrates (TC) were calculated by the following equation: TC = 100 – (%CP + %EE + %MM), while non-fiber carbohydrates (NFC) were calculated as the difference between TC and NDFap, as proposed by Sniffen et al. (1992). The metabolizable energy content was calculated as 82% of the digestible energy.

Forty-five days after the beginning of the performance trial, the digestibility trial was started, using 16 animals (four in each treatment) of the same 32 lambs, with an average body weight of 22.5 kg. Lambs were housed in individual metabolic cages equipped with feeders and drinkers to determine feed intake and digestibility.

**Table 1.** Centesimal composition of ingredients and chemical composition of experimental diets.

| Composition | Experimental diet[a] | | | |
|---|---|---|---|---|
| | C | CS | CE | CSE |
| Ingredient (% DM) | | | | |
| Ground corn | 7.93 | 0.22 | 7.90 | 0.22 |
| Soybean meal | 38.11 | 37.68 | 38.11 | 37.66 |
| Sunflower seed | - | 8.08 | - | 8.08 |
| Sugarcane | 49.92 | 50.10 | 49.92 | 50.00 |
| Mineral mix[b] | 0.49 | 0.49 | 0.49 | 0.49 |
| Iodized salt | 0.32 | 0.32 | 0.32 | 0.32 |
| Dicalcium phosphate | 0.81 | 0.81 | 0.81 | 0.81 |
| Urea | 1.33 | 1.14 | 1.33 | 1.15 |
| Calcitic limestone | 1.09 | 1.17 | 1.01 | 1.17 |
| Vitamin E | - | - | 0.10 | 0.10 |
| Chemical composition[c] | | | | |
| Dry matter[d] | 43.08 | 43.17 | 43.08 | 42.98 |
| Organic matter[e] | 93.41 | 93.22 | 93.44 | 93.18 |
| Mineral matter[e] | 6.59 | 6.78 | 6.56 | 6.82 |
| Crude protein[e] | 23.59 | 23.36 | 23.59 | 23.37 |
| Ether extract[e] | 1.48 | 3.36 | 1.48 | 3.36 |
| Lignin[e] | 2.76 | 2.75 | 2.76 | 2.75 |
| Neutral detergent fiber[e] | 27.72 | 30.30 | 27.72 | 30.27 |
| Acid detergent fiber[e] | 14.31 | 16.71 | 14.31 | 16.69 |
| Total carbohydrates[e,f] | 68.34 | 66.23 | 68.37 | 66.45 |
| Non-fibrous carbohydrates[e,g] | 40.62 | 36.19 | 40.65 | 36.18 |
| Metabolizable energy (Mcal kg$^{-1}$ DM) | 3.13 | 3.28 | 3.13 | 3.27 |

[a]Experimental diet: C = sugarcane + concentrate; CS = sugarcane + concentrate with sunflower seeds; CE = sugarcane + concentrate with 1,000 mg vitamin E kg$^{-1}$ dietary dry matter; and CSE = sugarcane + concentrate with sunflower seeds and 1,000 mg vitamin E kg$^{-1}$ dietary DM.

[b]Mineral mix: phosphorus 50 g; calcium 150 g; sodium 100 g; magnesium 5 g; sulfur 25 g; zinc 1,500 mg; manganese 500 mg; cobalt 10 mg; iodine 40 mg; selenium 10 mg.

[c]Analyses performed at the Laboratory of Animal Nutrition (LANA) at FCAV – Unesp.

[d]%.

[e]% DM.

[f]Total carbohydrates = 100 – (%CP + %EE + %MM).

[g]Non-fibrous carbohydrates = total carbohydrates – neutral detergent fiber.

[h]Mcal kg$^{-1}$ DM.

Lambs remained 12 days in the cages: seven for adapting and five for total feces collection, controlling the feed intake. The daily amount of feces excreted was collected and weighed, and 10% of the total were stored in a freezer at –18 ºC. At the end of the collection period, samples were mixed to generate one composite sample per animal. The intake of nutrients was calculated as the difference between the amount of a given nutrient present in the feed supplied and the amount of that nutrient in the leftovers. Subsequently, the intake of each digestible nutrient was calculated by multiplying the amount of a given nutrient consumed by its digestibility, expressed in g animal$^{-1}$ day$^{-1}$.

The digestibility coefficients of DM, OM, CP, NDFap, ADF, TC, and NFC were calculated as the difference between the amounts ingested and excreted in the feces, using the following formula: Apparent digestibility (%) = ((nutrient ingested, in g – nutrient excreted in the feces, in g)/nutrient ingested, in g) × 100.

Upon reaching 32.0 ± 0.2 kg body weight (approximately 135 days of age), lambs were weighed and fasted for solids for 16 h. Prior to slaughter, animals were weighed again to determine body weight at slaughter (BWS) and fasted weight (FW). Lambs were stunned by electronarcosis with a 250 V electric shock for two seconds, using an Imafrig Ltd. Futura stunning device, and then the jugular veins and carotid arteries were sectioned for bleeding, respecting the procedures that characterize humane slaughter. After skinning and evisceration, the gastrointestinal tract content (measured as the difference between full and empty gastrointestinal tract) was used in the determination of the empty body weight (EBW = BWS – gastrointestinal content – gallbladder content – bladder content) and dressing percentage (DP = (HCW – EBW)*100).

After evisceration, carcasses were weighed, generating the hot carcass weight (HCW), which was used to determine the hot carcass yield (HCY = HCW/BWS × 100), and transferred to a cold room at 4 ºC, where they remained 24 h hung by the *Gastrocnemius* tendons on appropriate hooks, spaced 17 cm apart by the extremities. After this period, the cold carcass was weighed (CCW), so the chilling loss could be calculated (CL = (HCW – CCW/HCW) × 100). Conformation, which considers the distribution of muscle masses on the bone base, was evaluated subjectively always by the same person, according to Colomer-Rocher et al. (1988). Next, carcass morphological measurements were taken according to Osório et al. (1998), and the carcass compactness index ((CCI, kg/cm) = CCW/CIL (carcass internal length)) and leg compactness index (LCI = rump width/leg length) were calculated.

Later, the carcasses were divided lengthwise, and the left half was sectioned into five anatomical regions – neck, shoulder, ribs, loin, and leg – following Silva Sobrinho (2006), which were weighed individually to determine the representativeness in percentage values.

Measurements were taken in the dorsal portion of the *Longissimus lumborum* muscle, at the 12th and 13th thoracic ribs, to determine the loin eye area (LEA), calculated by the formula (A/2 × B/2)π, proposed by Silva Sobrinho et al. (2003), where A is the maximum length and B is the maximum depth of the muscle, in cm. Additionally, measurements C (fat cover thickness) and GR (maximum cover thickness over the side part of the loin at 11 cm from the midline, in cm) were obtained using a digital caliper and a tape measure.

The experimental design was completely randomized, in a 2 × 2 factorial arrangement (with and without sunflower seeds and with or without vitamin E, on the diet DM basis). Data were subjected to analysis of variance by the F test at 5% significance level. When significant differences were detected between treatments for the different variables studied, they were compared by Tukey's test at the same significance level.

## Results and Discussion

Lambs that remained on average 75 days confined consumed 793.43 g dry matter per day, which represented 3.36% of their body weight (BW) and a feed conversion of 3.44 kg DM intake $kg^{-1}$ weight gain. There was no interaction (P>0.05) between sunflower seeds and vitamin E for the analyzed variables, or differences (P>0.05) between treatments for initial body weight (IBW), final body weight (FBW), body weight at slaughter (BWS), days in the feedlot (DF), dry matter intake per day and per metabolic weight (DMI), and feed conversion (FC).

Dry matter intakes expressed in g animal$^{-1}$ day$^{-1}$, unit of metabolic size (g kg$^{-0.75}$ day$^{-1}$), and percentage of body weight (% BW) were not influenced (P>0.05) by treatments, which may be because the diets had similar NDF contents and protein and energy values (Table 1). The same response was reported by Homem Junior et al. (2010), who did not observe differences in DM intake adding lipid sources to diets for Santa Ines lambs.

However, the average daily weight gain (ADG) was higher (P<0.05) in treatments with addition of vitamin E (Table 2). The NRC (2007) recommends 15 to 30 mg vitamin E kg$^{-1}$ DM for growing sheep; however, it reports that levels above these, especially for growing animals, may improve the animal performance, as was observed in the present study. In a similar experiment, Wulf et al. (2003) added 1,000 mg vitamin E day$^{-1}$ to the diet of castrated lambs and observed a positive effect on weight gain. Macit et al. (2003) supplemented 45 mg day$^{-1}$ vitamin E in diets for Awassi sheep and reported a 6.7% improvement in daily weight gain.

**Table 2.** Performance of lambs fed diets with and without sunflower seeds and vitamin E.

| Variable | Sunflower seeds (S) | | Vitamin E (E) | | S | E | Interaction (S × E) | |
|---|---|---|---|---|---|---|---|---|
| | With | Without | With | Without | p | p | p | CV (%) |
| IBW (kg) | 15.04 | 14.99 | 15.03 | 15.00 | 0.570 | 0.780 | 0.610 | 1.32 |
| FBW (kg) | 32.24 | 32.09 | 32.26 | 32.07 | 0.330 | 0.190 | 0.910 | 1.01 |
| BWS (kg) | 30.28 | 30.19 | 30.20 | 30.28 | 0.670 | 0.690 | 0.860 | 1.57 |
| DF (days) | 76.90 | 72.80 | 71.90 | 77.80 | 0.210 | 0.080 | 0.550 | 9.47 |
| DMI (g day$^{-1}$) | 770.55 | 816.32 | 800.42 | 786.44 | 0.080 | 0.580 | 0.800 | 7.06 |
| DMI (g kg$^{-0.75}$day$^{-1}$) | 71.87 | 76.38 | 74.64 | 73.60 | 0.060 | 0.650 | 0.790 | 6.93 |
| DMI (%BW) | 3.26 | 3.47 | 3.39 | 3.34 | 0.060 | 0.670 | 0.780 | 6.89 |
| ADG (kg) | 0.225 | 0.237 | 0.241$^{a}$ | 0.221$^{b}$ | 0.150 | 0.030 | 0.650 | 8.31 |
| FC (DMI WG$^{-1}$) | 3.44 | 3.43 | 3.30 | 3.57 | 0.930 | 0.060 | 0.670 | 8.88 |

$^{a,b}$Means followed by different letters in the row differ by Tukey's test at 5% probability level; CV = coefficient of variation; IBW = initial body weight; FBW = final body weight; BWS = body weight at slaughter; DF = days in the feedlot; DMI = dry matter intake; BW = body weight; ADG = average daily weight gain; FC = feed conversion; WG = weight gain;

Crude protein intake did not differ (P>0.05) between treatments, averaging 157.68 g day$^{-1}$ (Table 3). Likewise, the intakes of OM, NDF, and ADF were not influenced (P>0.05) by addition of sunflower seeds and vitamin E to the diets. The similarity between treatments for intake was probably caused by the similar NDF contents and protein and energy values of the diets (Table 1).

Addition of sunflower seeds to lamb diets, irrespective of the use of vitamin E, influenced (P<0.05) the intakes of EE, TC, and NFC (Table 3). Ether extract intake (20.91 g day$^{-1}$) by the lambs from the treatment with sunflower seeds was higher than the others (9.54 g day$^{-1}$), which is a direct impact of the concentration of this nutrient in the diet (Table 1). The intakes of TC and NFC of the lambs decreased from 459.46 and 304.42 g day$^{-1}$ when they received diets without inclusion of sunflower seeds to 394.81 and 242.47 g day$^{-1}$ with the diets containing the ingredient. Corn is the main quantitative source of carbohydrates in the diet of production animals, and when it is replaced with sunflower seeds, which contain lower amounts of these nutrients in their composition, the concentration of carbohydrates decreases, and consequently so does their intake. The intakes of EE, TC, and NFC observed in this study corroborate those obtained by Homem Junior et al. (2010), who evaluated inclusion of sunflower seeds in diets for feedlot Santa Ines lambs and reported higher EE intake and lower TC and NFC intakes when the seeds were added to the diets.

**Table 3.** Voluntary intake of nutrients (g) and gross energy (Mcal) obtained in the digestibility trial of lambs fed diets with and without sunflower seeds and vitamin E.

| Variable (g/day) | Sunflower seeds (S) | | Vitamin E (E) | | S | E | Interaction (S × E) | |
|---|---|---|---|---|---|---|---|---|
| | With | Without | With | Without | p | p | p | CV (%) |
| DM | 770.555 | 816.32 | 800.42 | 786.44 | 0.086 | 0.585 | 0.806 | 7.06 |
| OM | 504.322 | 565.49 | 543.75 | 526.06 | 0.090 | 0.609 | 0.835 | 14.17 |
| CP | 149.28 | 166.07 | 159.37 | 155.98 | 0.106 | 0.733 | 0.760 | 13.90 |
| EE | 20.91[a] | 9.54[b] | 15.09 | 15.37 | 0.001 | 0.798 | 0.919 | 15.89 |
| NDF | 152.78 | 155.04 | 157.30 | 150.51 | 0.851 | 0.574 | 0.816 | 17.19 |
| ADF | 65.92 | 56.68 | 61.65 | 60.96 | 0.149 | 0.911 | 0.627 | 22.22 |
| TC | 394.81[b] | 459.46[a] | 435.90 | 428.37 | 0.029 | 0.526 | 0.885 | 14.17 |
| NFC | 242.47[b] | 304.42[a] | 279.04 | 267.85 | 0.001 | 0.487 | 0.965 | 12.87 |

[a,b]Means followed by different letters in the row differ by Tukey's test at 5% probability level; CV = coefficient of variation; DM = dry matter; OM = organic matter, CP = crude protein; EE = ether extract; NDF = neutral detergent fiber; ADF = acid detergent fiber; TC = total carbohydrates; NFC = non-fibrous carbohydrates.

The digestibility coefficients of DM and nutrients were similar (P>0.05) with and without inclusion of sunflower seeds and vitamin E, except for the variables EE and NFC, which were altered (P<0.05) with the inclusion of sunflower seeds (Table 4). There was an increase (P<0.05) from 68.46 to 85.34% in the digestibility coefficient of EE when the animals were fed diets containing sunflower seeds, which was probably due to the higher ether extract content of these diets (Table 1). Silva et al. (2007) stressed that lipid sources are good substitutes for the fermentable carbohydrates originating from corn because they have a high energy density, even though their inclusion in lamb diets reduces the digestibility of NFC. In the present study, the digestibility coefficient of NFC decreased (P<0.05) from 93.07 to 91.28%, probably due to the lower NFC intake (Table 3) by the animals fed diets with sunflower seed, affecting their use.

Table 5 shows the results for the carcass morphological measurements, which were not influenced (P>0.05) by the treatments. The fact that there was no significance in the carcass measurements may be related to the standardization of slaughter according to body weight, since animals of the same breed and age, with similar body weights, show similar carcass morphological measurements. Similarly, the carcass compactness index (0.24 $kg^{-1}$ cm) and leg compactness index (0.64), as well as the conformation (2.55) and fatness (2.40) scores were not affected (P>0.05) by treatments. These values corroborate Macedo et al. (2008), who evaluated the morphological measurements of the carcass of Suffolk crossbred lambs fed diets containing up to 19.80% sunflower seeds and slaughtered with 28 kg BW and did not observe differences in conformation (2.78), fatness (2.75), or compactness indices of carcass (0.27 kg $cm^{-1}$) and leg (0.63 kg $cm^{-1}$). Macit et al. (2003) and Homem Junior et al. (2010) also did not observe differences in morphological measurements of carcasses of lambs consuming vitamin E and sunflower seeds, respectively.

**Table 4.** Digestibility coefficients of nutrients and gross energy obtained in the digestibility trial of lambs fed diets with and without sunflower seeds and vitamin E.

| Variable (%) | Sunflower seeds (S) | | Vitamin E (E) | | S | E | Interaction (S × E) | |
|---|---|---|---|---|---|---|---|---|
| | With | Without | With | Without | p | p | p | CV (%) |
| DC-DM | 77.36 | 76.50 | 77.20 | 76.67 | 0.485 | 0.663 | 0.816 | 3.09 |
| DC-OM | 80.06 | 80.28 | 80.51 | 79.82 | 0.872 | 0.613 | 0.735 | 3.31 |
| DC-CP | 79.69 | 83.66 | 81.83 | 81.52 | 0.103 | 0.895 | 0.920 | 5.49 |
| DC-EE | 85.34[a] | 68.46[b] | 77.08 | 76.71 | 0.001 | 0.866 | 0.794 | 5.53 |
| DC-NDF | 35.13 | 31.37 | 33.37 | 33.13 | 0.297 | 0.947 | 0.7946 | 20.72 |
| DC-ADF | 27.80 | 26.91 | 27.11 | 27.60 | 0.694 | 0.829 | 0.915 | 16.11 |
| DC-TC | 73.11 | 73.98 | 73.69 | 73.40 | 0.648 | 0.876 | 0.577 | 5.09 |
| DC-NFC | 91.28[b] | 93.07[a] | 92.26 | 92.09 | 0.001 | 0.789 | 0.317 | 1.37 |
| DC-GE | 83.11 | 79.27 | 83.93 | 79.44 | 0.147 | 0.147 | 0.841 | 6.09 |

[a,b]Means followed by different letters in the row differ by Tukey's test at 5% probability level; CV = coefficient of variation; DC = digestibility coefficient; DM = dry matter; OM = organic matter, CP = crude protein; EE = ether extract; NDF = neutral detergent fiber; ADF = acid detergent fiber; TC = total carbohydrates; NFC = non-fibrous carbohydrates; GE = gross energy.

**Table 5.** Morphological measurements of the carcass of lambs fed diets with and without sunflower seeds and vitamin E.

| Variable | Sunflower seeds (S) | | Vitamin E (E) | | S | E | Interaction (S × E) | |
|---|---|---|---|---|---|---|---|---|
| | With | Without | With | Without | p | p | p | CV (%) |
| Conformation[a] | 2.50 | 2.60 | 2.50 | 2.60 | 0.56 | 0.56 | 0.56 | 14.87 |
| Fatness[b] | 2.30 | 2.55 | 2.35 | 2.50 | 0.15 | 0.37 | 0.76 | 15.29 |
| CEL (cm) | 53.80 | 54.80 | 53.80 | 54.80 | 0.20 | 0.20 | 0.79 | 3.12 |
| CIL (cm) | 56.20 | 55.70 | 56.50 | 55.40 | 0.24 | 0.58 | 0.16 | 3.60 |
| LL (cm) | 32.80 | 34.30 | 33.30 | 33.80 | 0.27 | 0.71 | 0.94 | 8.89 |
| CC (cm) | 66.55 | 67.25 | 67.00 | 66.80 | 0.32 | 0.77 | 0.32 | 2.31 |
| TC (cm) | 37.20 | 36.15 | 36.50 | 36.85 | 0.43 | 0.79 | 0.39 | 8.04 |
| RC (cm) | 60.75 | 61.05 | 60.50 | 61.30 | 0.58 | 0.15 | 0.58 | 1.98 |
| RW (cm) | 21.77 | 21.80 | 21.69 | 21.88 | 0.97 | 0.82 | 0.68 | 8.70 |
| CW (cm) | 24.01 | 23.65 | 23.85 | 23.81 | 0.41 | 0.92 | 0.14 | 9.99 |
| CD (cm) | 24.14 | 24.23 | 23.96 | 24.41 | 0.79 | 0.21 | 0.55 | 3.19 |
| CCI (kg $cm^{-1}$) | 0.24 | 0.24 | 0.23 | 0.25 | 0.84 | 0.75 | 0.13 | 6.68 |
| LCI | 0.66 | 0.63 | 0.65 | 0.64 | 0.64 | 0.52 | 0.87 | 13.54 |

Means followed by different letters in the row differ by Tukey's test at 5% probability level; [a]Score of 1 to 5, where 1= very poor and 5= excellent. [b]Score of 1 to 5, where 1 = absent fat and 5 = excess fat; CV = coefficient of variation; CEL = carcass external length; CIL = carcass internal length; LL = leg length; CC = chest circumference; TC = thigh circumference; RC = rump circumference; RW = rump width; CW = maximum chest width; CD = chest depth; CCI = carcass compactness index; LCI = leg compactness index.

Considering the mean values for carcass fatness, the higher ether extract contents stemming from inclusion of sunflower in the diets (Table 1) was assumed to result in greater fat deposition, which was not observed. The carcass compactness index of 0.24 was similar to those found in the literature for lambs, with values ranging from 0.24 to 0.29 (ZUNDT et al., 2006).

According to Silva and Pires (2000), the quantitative evaluation of the carcass has a relevance in the judgment of the performance attained by the animal during its development, in addition to being fundamental to the production process and relating to the end product, since it estimates the amount of meat produced available for sale. There was no difference (P>0.05) in the variables analyzed in the animal carcass (Table 6). Results found for HCW and CCW were similar to those obtained by Macedo et al. (2008), who reported 13.89 kg HCW and 13.53 kg CCW in Suffolk lambs fed diets containing different levels of sunflower seeds and slaughtered with 28 kg BW.

**Table 6.** Quantitative carcass traits and percentages of cuts from the left half-carcass of lambs fed diets with and without sunflower seeds and vitamin E.

| Variable | Sunflower seeds (S) | | Vitamin E (E) | | S | E | Interaction (S × E) | CV (%) |
|---|---|---|---|---|---|---|---|---|
| | With | Without | With | Without | p | p | p | |
| HCW (kg) | 13.73 | 14.07 | 13.67 | 14.13 | 0.200 | 0.094 | 0.604 | 4.14 |
| CCW (kg) | 13.31 | 13.39 | 13.10 | 13.69 | 0.536 | 0.058 | 0.795 | 4.80 |
| HCY (%) | 45.32 | 46.60 | 45.27 | 46.66 | 0.171 | 0.139 | 0.672 | 4.34 |
| CCY (%) | 43.92 | 44.67 | 43.39 | 45.20 | 0.455 | 0.082 | 0.846 | 4.92 |
| DP (%) | 54.16 | 54.93 | 54.74 | 54.35 | 0.435 | 0.686 | 0.386 | 3.96 |
| CL (%) | 3.13 | 4.10 | 4.12 | 3.11 | 0.382 | 0.364 | 0.665 | 66.75 |
| LHCW (kg) | 6.61 | 6.84 | 6.50 | 6.95 | 0.560 | 0.063 | 0.834 | 4.75 |
| Neck (%) | 8.32 | 7.89 | 7.85 | 8.20 | 0.270 | 0.505 | 0.715 | 14.22 |
| Shoulder (%) | 20.88 | 20.47 | 20.77 | 20.58 | 0.463 | 0.765 | 0.998 | 7.20 |
| Ribs (%) | 25.11 | 25.58 | 25.38 | 25.32 | 0.581 | 0.825 | 0.296 | 5.99 |
| Loin (%) | 10.74 | 10.96 | 10.92 | 10.79 | 0.621 | 0.974 | 0.211 | 10.31 |
| Leg (%) | 35.25 | 34.65 | 35.23 | 34.68 | 0.352 | 0.345 | 0.159 | 4.53 |

[a,b]Means followed by different letters in the row differ by Tukey's test at 5% probability level; CV = coefficient of variation; HCW = hot carcass weight; CCW = cold carcass weight; HCY = hot carcass yield; CCY = cold carcass yield; DP = dressing percentage; CL = chilling loss; LHCW = left half-carcass weight.

The cold carcass yield, which, according to Sañudo and Sierra (1986), can be influenced by the feeding system, ranged from 43.39 to 45.20% and remained close to the 44.5% recommended by Silva Sobrinho (2006). According to Grande et al. (2009), the chilling loss corresponds to the difference in weight before and after the carcass is chilled, and depends mainly on the conformation, fatness, and moisture loss. Thus, the larger the fat cover, the lower the chilling losses, given the increased protection provided to the carcass. The carcass chilling loss observed here (3.61%) was higher than the 1.94% obtained by Macedo et al. (2008). The mean value of 1.91 cm found for the fat cover of the carcasses (Table 7) was likely responsible for this greater weight loss from chilling.

Cuts' yields were 8.07% for neck, 20.70% for shoulder, 25.35% for ribs, 10.85% for loin, and 34.95% for leg (Table 6). The percentage evaluations of the different carcass cuts help in the selection of breeds and/or genetic groups that produce higher proportions of valued edible cuts and enable a quantitative assessment, as the carcass should have the best proportion possible of cuts with greater participation of muscles. The leg is the commercial cut of highest value in sheep carcass, and thus it is interesting that its proportion in the carcass be higher. Results for neck (8.06%), shoulder (20.68%), and leg (24.95%) yields obtained in the present study were similar to those observed by Macedo et al. (2008), who analyzed the carcass of Suffolk crossbred lambs fed diets containing up to 19.80% sunflower seeds and reported yields of 7.67% for neck, 20.84% for shoulder, and 34.35% for leg. According to Ortiz et al. (2005), in studies with lambs for meat production, these variables usually do not vary largely.

**Table 7.** Measurements of the *Longissimus lumborum* muscle of lambs fed diets with and without sunflower seeds and vitamin E.

| Variable | Sunflower seeds (G) | | Vitamin E (E) | | S | E | Interaction (S × E) | |
|---|---|---|---|---|---|---|---|---|
| | With | Without | With | Without | P | P | P | CV(%) (%) |
| Measurement A (cm) | 5.69 | 5.47 | 5.52 | 5.64 | 0.531 | 0.726 | 0.622 | 13.25 |
| Measurement B (cm) | 2.65 | 2.66 | 2.69 | 2.62 | 0.961 | 0.701 | 0.699 | 15.26 |
| Measurement C (cm) | 1.85 | 1.96 | 1.91 | 1.90 | 0.580 | 0.956 | 0.214 | 23.11 |
| Measurement GR (cm) | 2.06 | 2.25 | 2.06 | 2.26 | 0.498 | 0.427 | 0.474 | 25.67 |
| LEA ($cm^2$) | 11.94 | 11.59 | 11.71 | 11.82 | 0.531 | 0.257 | 0.050 | 15.79 |

[a,b]Means followed by different letters in the row differ by Tukey's test at 5% probability level; CV = coefficient of variation; Measurement A = maximum length of the L*ongissimus lumborum* muscle; Measurement B = maximum depth of the *Longissimus lumborum* muscle; Measurement C = minimum fat thickness over the L*ongissimus lumborum*; Measurement GR = maximum fat thickness over the side part of the loin at 11 cm from the midline; LEA = loin-eye area, obtained by the formula (A/2 × B/2) π.

Inclusion of sunflower seeds and vitamin E in the lamb diets did not influence (P>0.05) measurements A, B, C, or GR of the *Longissimus lumborum* muscle of the lambs (Table 7). The loin eye area obtained by the formula (A/2 × B/2)π proposed by Silva Sobrinho et al. (2003) was 11.76 $cm^2$, and is in line with the recommended range (8 to 14 $cm^2$) for lambs slaughtered weighing 15 to 40 kg (SILVA SOBRINHO, 2006). This value was higher than the 10.30 $cm^2$ observed by Homem Junior et al. (2015), who evaluated the influence of supplementation with sunflower seeds on the LEA of the *Longissimus* muscle of lambs. The minimum fat thickness (measurement C) was below the minimum of 3 cm recommended by Silva Sobrinho (2006) for sheep carcasses; i.e., all treatments resulted in deficient fattening.

Measurements A and B of the *Longissimus* muscle have been studied by many researchers for being highly correlated with the proportion of muscle in the sheep carcass, besides LEA (PINHEIRO et al., 2009). Measurements A and B (5.58 and 2.65 cm) were similar to the 5.32 and 2.86 cm respectively, observed by Garcia et al. (2003), taken at the *L. dorsi* muscle of Suffolk crossbred lambs slaughtered with 31 kg BW, and by Siqueira and Fernandes (2000), who evaluated the carcass of Corriedale lambs slaughtered with 31 kg and reported values of 5.10 and 2.40 for the same measurements.

The lipid level in the diets was low (Table 1), which likely influenced the lack of differences observed between treatments for the quantitative variables of carcass and commercial cuts. Nevertheless, despite the low lipid level of the diets, Sales et al. (2013) and Almeida et al. (2014), evaluating the qualitative and nutritional aspects, respectively, of meat from the same animal used in this experiment, reported benefits from a diet with inclusion of sunflower seeds and vitamin E on the meat water-holding capacity and shear force, as well as an improvement in fatty acid profile, with an increase in conjugated linoleic acid (CLA), among others.

## Conclusions

Sunflower seeds and vitamin E are satisfactory alternative sources that can be included in the concentrate for feedlot lambs, providing good performance and quality carcasses.

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