Effect of yeast (Saccharomyces cerevisiae) associated or not to micro minerals in chemical composition, tissue composition, lipid oxidation and quality of meat of feedlot lambs

Efeitos da levedura (Saccharomyces cerevisiae) associada ou não a micro minerais na composição química e tecidual, oxidação lipídica e qualidade da carne de cordeiros confinados

Efectos de la levadura (Saccharomyces cerevisiae) asociada o no con micro minerales sobre la composición química y tisular, la oxidación de lípidos y la calidad de la carne de corderos confinados

Received: 10/26/2020 | Reviewed: 10/30/2020 | Accept: 11/04/2020 | Published: 11/08/2020

Leticia Jalloul Guimarães
ORCID: https://orcid.org/0000-0001-9768-7977
Universidade do Oeste Paulista, Brasil
E-mail: leticia_jg@hotmail.com

Lucas Ferreira Santiago
ORCID: https://orcid.org/0000-0003-3870-4049
Universidade do Oeste Paulista, Brasil
E-mail: lucas@unoeste.br

Juliana Pampana Nicolau
ORCID: https://orcid.org/0000-0002-4595-5308
Universidade do Oeste Paulista, Brasil
E-mail: julianapampana@yahoo.com.br

Fabiola Cristine de Almeida Rego
ORCID: https://orcid.org/0000-0003-4516-7632
Universidade do Norte do Paraná, Brasil
E-mail: fabiola.cristine@kroton.com.br

Caliê Castilho
ORCID: https://orcid.org/0000-0003-3300-8116
Universidade do Oeste Paulista, Brasil
E-mail: calie@unoeste.br
Luis Fernando Cunha Filho
ORCID: https://orcid.org/0000-0003-3609-868X
Universidade do Norte do Paraná, Brasil
E-mail: luiz.cunha@unopar.br

Francine Mezzomo Giotto
ORCID: https://orcid.org/0000-0001-6091-7337
University of Nevada Reno, Estados Unidos
E-mail: frangiotto@msn.com

Marilice Zundt
ORCID: https://orcid.org/0000-0001-9551-9195
Universidade do Oeste Paulista, Brasil
E-mail: mari@unoeste.br

Abstract
Growth promoters are increasingly restricted in ruminants’ diet. By the need to find safer alternatives for the environment and meat consumers the yeast in probiotics being an alternative. Chemical and tissue composition, lipid oxidation and sensorial quality of meat lambs supplemented with yeast (Saccharomyces cerevisiae), associated or not with the micro minerals, finished in feedlot was evaluated. 24 male lambs, Texel breed lambs divided into three experimental groups (n = 8 lambs / group) CON (without addition of yeast (Saccharomyces cerevisiae)), PB (constituted by yeast Saccharomyces cerevisiae) and PBM (constituted by yeast Saccharomyces cerevisiae + selenium and chrome). After slaughter of the lambs (mean live weight of 55.1 kg), the carcasses were refrigerated for 24 hours, sectioned in the medium for analysis of the Longissimus lumborum muscle. No significant values (P>0.05) were observed for the most qualitative analyzes, except for fat (%) in the proximate composition, with highest values for PBM (5.62%) when compared to CON and PB (P <0.05). The supplementation with yeasts containing or not the micro minerals, did not alter the parameters analyzed, indicating good acceptance and quality of the meat.

Keywords: Probiotic; Proximate composition; Sensory analysis; Sheep.

Resumo
Promotores de crescimento são cada vez mais restrito na nutrição de ruminantes, havendo a necessidade da busca por alternativas seguras para o meio ambiente e os consumidores de carne, sendo as leveduras dos probióticos uma alternativa. Neste estudo investigou-se a
composição química e tecidual, oxidação lipídica e qualidade sensorial da carne de cordeiros suplementados com levedura (Saccharomyces cerevisiae) associada ou não a micro minerais, terminados em confinamento. Foram utilizados 24 cordeiros machos, da raça Texel, divididos em 3 tratamentos (n = 8 cordeiros/tratamento) sendo eles CON (sem a adição da levedura), PB (com adição da levedura Saccharomyces cerevisiae) e PBM (com adição da levedura com micro minerais (selênio e cromo). Após o abate (peso médio de abate 55.1 kg), as carcaças foram refrigeradas por 24 horas, sendo cortadas ao meio para as análises no músculo Longissimus lumborum. Não houve efeito significativo (P>0.05) para a maioria das análises qualitativas, exceto para a gordura na composição centesimal, com maiores valores para o tratamento PBM (5.62%) quando comparado aos tratamentos CON e PB (<0.05). A suplementação com levedura associada ou não a micro minerais não altera os parâmetros analisados, indicando uma boa aceitação e qualidade da carne.

**Palavras-chave:** Análise sensorial; Composição centesimal; Ovino; Probiótico.

**Resumen**

Los promotores del crecimiento están cada vez más restringidos en la nutrición de los rumiantes, con la necesidad de buscar alternativas seguras para el medio ambiente y los consumidores de carne, siendo las levaduras probióticas una alternativa. Este estudio investigó la composición química y tisular, la oxidación lipídica y la calidad sensorial de la carne de cordero suplementada con levadura (Saccharomyces cerevisiae) asociada o no a microminerales, terminada en confinamiento. Se utilizaron veinticuatro corderos Texel machos, divididos en 3 tratamientos (n = 8 corderos / tratamiento) siendo CON (sin la adición de levadura), PB (con la levadura Saccharomyces cerevisiae) y PBM (con la adición de levadura con microminerales (seleno y cromo). Después del sacrificio (peso medio de sacrificio 55.1 kg), las canales se refrigeraron durante 24 horas, y se cortaron por la mitad para su análisis en el músculo Longissimus lumborum. No hubo efecto significativo (P> 0.05) para la mayoría de los análisis cualitativos, a excepción de la grasa en la composición próxima, con valores más altos para el tratamiento PBM (5,62%) en comparación con los tratamientos CON y PB (<0,05). La suplementación con levadura asociada o no a microminerales no altera los parámetros analizados que indican buena aceptación y calidad de la carne.

**Palabras clave:** Análisis sensorial; Oveja; Perfil nutricional de la carne; Probióticas.
1. Introduction

World sheep herd is growing and according to FAO (2018) the world has 1,209,467,079 sheep heads. In Brazil, sheep meat importation has increase 5.5% (CNA 2017), and Brazilian sheep production has showing a solid and linear increase by the increase in demand for sheep meat. It is estimated that in Brazil has 511758 farm sheep, with a total, proximately, 18947352 sheep (IBGE, 2018).

Growth promoters, mostly antibiotics, are increasingly restricted in ruminants’ diet. By the need to find safer alternatives for the environment and meat consumers, probiotics have been used in ruminants diet as an alternative additive that improves the nutrient use by ruminants, improve the population establishment of desirable microorganisms in the intestinal flora, preventing colonization by enteropathogens (Uyeno et al., 2015).

Probiotics are live strains of microorganisms living when administered in adequate amounts, confer a benefit to the health of the host (Markowiak; Ślizewka, 2018). Probiotics work in the maintenance of intestinal flora balance, in harmony with digestive functions and animal health, improving the animal production (Pinheiro et al., 2007).

Advances in animal nutrition studies, especially in the micro minerals area, have shown greater response in ruminant productivity. Selenium acts in the immunologic system, decreases health disorders, protects against oxidative stress (Quin et al., 2007), and improve carcass quality (Domínguez-Varaa et al., 2009).

Meanwhile, chrome acts directly on insulin cells sensitivity and glucose metabolism (NRC, 2007), therefore improving nutrients digestion in animals’ feedlot. Therefore, the aim of this study was to evaluate the effect of yeast (Saccharomyces cerevisiae) supplementation in addition or not to micro minerals (chrome and selenium) on proximate composition, tissue composition, lipid stability, fresh quality parameters, and sensory of lamb meat.

2. Methodology

Experimental area and Ethics Committee

The study was carried out in the Animal Science Center at the University of Oeste Paulista located in Presidente Prudente, SP, Brazil. All experimental procedures were conducted in accordance with the current law of the country and were approved by the Ethics Committee of Animal Experimentation (no. 4217).
**Animals, diets, and sample collection**

Twenty-four Texel ram lambs, with approximately 120 days of age and 29.20 ± 2.44 kg of body weight were randomly assigned to 1 of 3 dietary treatment (n=8 per treatment). Diets were formulated to attend the nutritional requirements according to NRC (2007) for lambs and potential daily gain of 250 g, with Coast cross hay and commercial diet® (base control diet) offered in a concentrate: roughage ratio of 80:20 (Table 1). Animals were fed ad libitum, three times a day (7 AM, 12 AM and 4 PM), and refusals were allowed at 5% of offered feed.

Dietary treatments consisted in Control (CON): base control diet; Probiotic (PB): control + 5 grams yeast/animal/day (Saccharomyces cerevisiae, Yea Sacc® cepa 1026, 1x108 CFU/g); Probiotic Mineral (PBM): control + 3 grams yeast/animal/day (Saccharomyces cerevisiae, Beef Sacc® strain 1026, 5x106 CFU/g) + selenium organic (500 mg/kg) + chromium (300 mg/kg).

The techniques described by Mizubuti et al. (2009) were used to determine the chemical composition of the diet (Table 1). The content of total digestible nutrients (TDN) was estimated according to Cappelle et al. (2001).

**Table 1.** Chemical composition of ingredients (% of dry matter) of total diet in feedlot of lambs, supplemented with yeasts (*Saccharomyces cerevisiae*) associated or not to micro minerals in chemical composition.

| Ingredients (%) | Hay     | Concentrate | Total diet (Hay + Concentrate) |
|-----------------|---------|-------------|--------------------------------|
| Dry Matter      | 89.07   | 92.04       | 91.44                          |
| Mineral Matter  | 3.87    | 16.97       | 14.35                          |
| Crude Protein   | 8.32    | 18.7        | 16.62                          |
| Ether Extract   | 1.57    | 3.41        | 3.04                           |
| Raw Fiber       | 34.10   | 5.8         | 11.46                          |
| Acid Detergent  | 43.89   | 65.85       | 61.85                          |
| Fiber (ADF)     |         |             |                                |
| Total Digestible Nutrients (TDN) | 55.5 | 73.00 | 69.5 |

1 Estimated according to Capelle et al 2001. Source: Elaborated by the authors.
As can be observed in Table 1, before being given for the animals the hay, concentrate and total diet (hay+concentrate) was analyzed according to AOAC (1995).

Feeding times were 8h00 and 17h00. Leftover feed was weighed daily, and the amount provided was adjusted according to the previous day’s intake to allow there to be leftovers of 15% of the total DM offered. The animals had unrestricted access to water.

Animals were fed for 120 days and were slaughtered with an average body weight of 55.1 kg ± 2.40 and seven months old. After slaughtered, carcasses were chilled, and the M. Longissimus thoracis et lumborum was excised from loins 24 h post-mortem (Osório; Osório, 2005).

**pH, proximate and tissue composition, loin eye area and marbling**

The muscle used was Longissimus lumborum (2.54 cm) and then the pH was assessed by using a Hanna® pH meter. Proximate composition (moisture, ash, protein (N x 6.25) and fat content were determined according AOAC (2005) Silva and Queiroz (2002).

Tissue composition according methodology described by Osório et al. (1998), in which 24 loins which had been previously stored and were then gradually thawed while being kept at a temperature of approximately 4 °C for 24 hours, were dissected, and calculated on natural-matter basis.

Loin-eye area (LEA) was measured on the Longissimus dorsi muscle from the left half of the carcass, by making a transverse section between the 12th and 13th ribs and outlining it on tracing paper. The area was then determined as square centimeters of the image using AUTO/CAD® software (Costa et al., 2012). Degree of marbling was subjectively assessed using photographic standards (1 - traces of marbling and 10 - abundant marbling) (AMSA, 2001).

**Cooking loss and shear force**

Cooking for shear force and sensory analysis was performed by thawing the lamb chops for 24 h at 4 °C and grilling to 71 °C (AMSA 2016). After being removed from the grill, chops rested for 30 min prior to final weighing. For shear force, chops were cooled for 24 h at 4 °C and 6 cores (1.27 cm in diameter) were removed from each sample with a drill press parallel to muscle fiber orientation. Cores were sheared with a C3 Texture Analyzer Brookfield® (Brookfield Engineering, Middleboro, MA), with a Warner-Bratzler blade.
For cooking loss (CKL), these samples were previously weighed and roasted in a pre-heated gas oven at 170°C until a temperature of 71°C was reached at the geometric center; measurements were taken using a digital thermometer. After cooking, the samples were cooled at room temperature (25–30°C) and weighed again. The weight loss by cooking was calculated by the difference between the weight of the refrigerated and roasted meat, expressed as a percentage of the initial weight (AMSA, 2015).

Instrumental color and lipid oxidation

Objective color (L*, a*, b*) was recorded by using a CR-10 Konica Minolta® color reader after 30 minutes of blooming, according to the methodology described by Houben et al. (2000). For lipid oxidation, was used the Thiobarbituric Acid Assay (TBA) according the methodology described by Pikul et al. (1989). Lipid oxidation (TBA values) was expressed as malonaldehyde concentration (mg of MDA / kg of meat) and the quantification was realized comparing samples to standards absorbance.

Sensory analysis

For sensory analysis, a total of 8 trained panelists evaluate a scale of intensity and characterization according ABNT (1993) guidelines, and to be eligible for participation, consumers had to be regular or occasional lamb consumers. A total of 8 chops were served in 3 sessions. Chops were randomly assigned to each panelist according to dietary treatment. Chops were cooked, trimmed of subcutaneous fat cover, and 8 cubes (2.54 cm × 1.27 cm × 1.27 cm) from each chop were served to the eight-member panel. Samples were served to panelists individually and unsalted crackers and water were available to the panelists to cleanse their palates between samples. Panelists evaluated juiciness from 1 = extremely dry to 7 = extremely juicy; tenderness from 1 = extremely tough to 7 = extremely tender; off-flavor intensity from 1 = extremely mild to 5 = extremely intense; and overall acceptability from 1 = extremely liked to 9 = extremely disliked.

Statistical analysis

Data were analyzed as a complete randomized design, with 3 treatments (control, probiotic, and probiotic mineral) and 8 experimental units per treatment. The homogeneity of
the variances was tested by the Bartletts’s test (P>0.05) and the normality of the residuals was verified by the Shapiro-Wilk test. The data were submitted to analysis of variance at 5% significance level, using the statistical software SAS. For sensory evaluation, the G-test was used, whereas panelist was the random effect.

3. Results

Table 2 has the results for pH, moisture, ash, tissue composition, loin eye area, marbling score and fat.

Table 2. pH, proximate composition, tissue composition, loin eye area (LEA), and marbling score of *Longissimus lumborum* from lambs in feedlot, supplemented with yeasts (*Saccharomyces cerevisiae*) associated or not to micro minerals in chemical composition.

| Variables          | Dietary Treatments | P Value |
|--------------------|--------------------|---------|
|                    | CON    | PB     | PBM    |         |
| pH                 | 5.52   | 5.48   | 5.49   | 0.874   |
| Moisture (%)       | 71.88  | 74.87  | 73.44  | 0.509   |
| Protein (%)        | 21.07  | 19.71  | 19.76  | 0.693   |
| Fat (%)            | 4.52<sup>b</sup> | 4.61<sup>b</sup> | 5.62<sup>a</sup> | 0.017   |
| Ash (%)            | 1.03   | 0.99   | 0.98   | 0.826   |
| Fat %              | 29.97  | 25.81  | 29.66  | 0.476   |
| Bone %             | 12.77  | 13.00  | 11.71  | 0.872   |
| Muscle %           | 57.26  | 61.19  | 58.63  | 0.502   |
| LEA (cm<sup>2</sup>) | 17.66  | 19.60  | 16.90  | 0.812   |
| Marbling (1-10)    | 1.87   | 1.75   | 1.63   | 0.484   |

Source: Elaborated by the authors.

Addition of yeast associated or not with micro minerals in lambs diets did not affect as variables (P>0.05) pH, moisture, protein, ash, tissue composition, loin eye area and marbling score (Table 2). Fat percentage in the lean was significant higher (P<0.05) from animals fed PBM when compared to animals fed PB, whereas values were similar for animals fed CON.

Qualitative characteristic evaluated in the muscle Longissimus lumborum from the lambs, can be observed in Table 3. No dietary effects (P>0.05) were observed for instrumental color, lipid oxidation, cooking loss, and shear force (Table 3).
Table 3. Instrumental color, lipid oxidation, cooking loss, and shear force of *Longissimus lumborum* from lambs in feedlot, supplemented with yeasts (*Saccharomyces cerevisiae*) associated or not to micro minerals in chemical composition.

| Dietary Treatments | CON  | PB   | PBM  | P Value |
|--------------------|------|------|------|---------|
| L*                 | 39.91| 38.94| 38.49| 0.567   |
| a*                 | 19.35| 18.30| 18.62| 0.682   |
| b*                 | 14.33| 13.48| 13.47| 0.352   |
| TBA (MDA mg/kg)    | 0.685| 0.793| 0.514| 0.207   |
| CKL %              | 25.43| 23.47| 21.32| 0.197   |
| WBSF kgf/cm²       | 3.46 | 3.57 | 3.60 | 0.813   |

Source: Elaborated by the authors.

The values for the variables L*, a*, b* was higher than the literature, and TBA, CKL obtained showed coherent averages for animals of this species (Sañudo et al., 2000, Rego et al 2019).

Evaluation parameters on meat (Table 4) for sensory attributes did not have dietary effects (P>0,05).

Table 4. Sensory attributes of *Longissimus lumborum* from lambs in feedlot, supplemented with yeasts (*Saccharomyces cerevisiae*) associated or not to micro minerals in chemical composition.

| Dietary Treatments | CON  | PB   | PBM  | P Value |
|--------------------|------|------|------|---------|
| Flavor intensity   | 2.63 | 2.63 | 2.75 | 0.950   |
| Tenderness         | 5.62 | 6.00 | 5.75 | 0.539   |
| Juiciness          | 3.13 | 2.63 | 3.00 | 0.796   |
| Overall Acceptability | 6.00 | 5.38 | 6.00 | 0.840   |

Source: Elaborated by the authors.
Average values for flavor intensity, tenderness, juiciness and overall acceptability was 2.7, 5.8; 2.95 and 5.8 respectively. The results are similar to those found by Grandis et al. (2016) and Ferrão et al. (2009).

4. Discussion

Chung et al. (2011) and Silberberg et al. (2013) found that supplementation with live yeasts (Saccharomyces cerevisiae), in grain-based diets for ruminants stabilize the ruminal pH of the animals, reducing drastic changes in pH, which results in greater stability of the rumen environment along the day, so improving the ruminal environment and favoring the production of energy for the animal as a whole.

However, in this research, no significant differences (p>0.05) were observed for none of the variables, but worth emphasizing that variable studies that were in accordance with good quality carcasses for the consumer market. The final pH results observed in this study were 5.49, and the values are in accordance to literature for ovine species (Sobrinho et al., 2005), indicating a proper resolution of the rigor mortis.

The pH found is consistent with several researches with the Texel breed in confinement, with lambs slaughtered between 30 and 45 kg, with variations between 5.4 to 5.8 (Lima et al., 2013; Rego et al., 2017; Rego et al., 2019); and the meat protein values are in accordance to Texel lambs slaughtered with an average of 35 kg (Rego et al., 2017; Rego et al., 2019).

Addition of probiotic in sheep diets contributes to increased weight gain because probiotic alter rumen microbial community making it more efficient digestion of plant material (Schofield et al., 2018) also the yeast (Saccharomyces cerevisiae) can increased the population of protozoa and stabilized the rumen pH on diets rich in rapidly fermentable starch (Jouany et al., 1998) and according to Signorini et al. (2012) the use of probiotics can improve the composition of products of animal origin, such as fat content for example.

Use micro mineral chromium can reduce de fat tissue in the carcass or the marbling in meat (Bhattacharya, et al. 2006; Arvizu et al., 2011; Kneeskern et al., 2016) and selenium can reduce or did not effect in the fat deposition in carcass or meat (Medeiros et al., 2012; Silva et al., 2020; Soldá et al., 2020) contrary to our results how show an increase in fat % proximate composition in PBM treatment compare to CON and PB treatment. Increase in fat % isn’t a desirable quality for the consumer, how prefer lean meat, but even with the highest fat % in PBM group did not affect the sensory analysis where the trained panelists did not differ the treatments.
For tissue composition results, muscle represents the most percent of the tissue, with average 59.02%, the fat stayed in second place with 28.48% and bone, in the last place, with 12.49%. For market and consumer this composition is important because have relationship with the economic value. Most percent of muscle, lower percent of bone and the appropriate fat percentage is the intended (Luchiari Filho, 2000).

According to Luchiari Filho (2000) LEA is an important predictor of commercial cuts yield. For LEA values from all treatments showed satisfactory muscle deposition for Texel lambs.

Marbling average was 1.73. Low values were expected as fat is the last tissue to be deposited (Rosa et al., 2002), so, young animals have lowest values for marbling, and, as well, castrated male lambs when compared to female and uncastrated animals.

CKL didn’t have difference between the treatments with 23.40%. This results are in according with the pH, because pH has direct influence on the water retention, color and tenderness (Bonacina et al., 2011).

The shear force average value was 3.54 kgf/cm² and the meat was classified as very soft according to Boleman et al. (1997) and Bickerstaffe et al. (1997). This result is also in accordance with studies from Gularte et al. (2000) and Santos et al. (2015) with Texel lambs.

Shear force been a variable with distinct results in the researches, with variations around 50% of magnitude.

Datas from three differents articles, with texel lamb breed, slaughtered before 6 months of age and feeded with highest concentrate diet (more than 60%), with the analysis did in the same machine, has variation for shear force in 3.1 to 7.9 kgf/cm² (Lima et al., 2013; Rego et al., 2019; Rego et al., 2017)

For sheep meat, color values are reported as L* 31.36 to 38.0, for a* 12.27 to 18.01 and for b* 3.34 to 5.65 (Bressan et al., 2001). In this study, meat average values of L* (39.11), a* (18.75) and b* (13.76) higher than the literature. The higher L* can be result the slaughter age as noted Souza et al. (2004). In this study with different slaughter lambs age noticed that youngest animals had higher L* when compared with oldest animals and the youngest animals had more water and lass fat in the muscle resulting in a higher L*, being that study the animal age slaughter was 7 months, namely, young animals.

The diet can also be responsible for the highest a* value as the most concentrate ratio has in the diet higher the a* value it will be (Coutinho et al., 2013). For the b* the highest value observed may be related to the ingestion of carotenoids contained in the roughage
(Fernandes et al., 2008) and also to bigger concentration of lipid intra and intermuscular (Costa et al., 2011).

The lipid degradation that occurs in meat cooking results in flavor compounds, which determine the different odors of meat of different species (Mottran 1998). Diets high in concentration result in higher concentration of branched chain fatty acids (Grandis et al., 2016). The odor felt by the light to moderate intensity tasters may be related to the higher concentrate diet.

Meat can be juicier if intramuscular fat content since the amount of intramuscular fat (marbling) from meat is one of the determining factors of juiciness (Osório et al., 2009). A result obtained in the sensory analysis of juiciness is directly related to the marbling of meat (Table 2) which is traces of marbling. The overall acceptability is affected by the consumer as stated by Osório et al. (2009) that, in order to achieve the “highest possible customer satisfaction”, not only must the desired characteristics be sought in food; but the consumer needs to be educated to better appreciate these characteristics.

Storage meat can promote a linear increase in TBA values (Fernandes et al., 2012), reducing the shelf life, but, TBA values below the 1.59 mg/kg of malonaldehyde concentration are considered acceptable because are imperceptible in sensory analysis (Torres; Okani 1997; Terra et al. 2006). In this study the TBA is 0.793 mg/kg, that is to say, it's acceptable and no have sensory losses to consumer.

5. Conclusion

Yeast supplementation with or without the addition of micro minerals in lambs diet did not affect meat quality parameters evaluate in this study, but Yeast supplementation with micro minerals increase fat % in proximate composition. However, new studies are necessary to evaluate the yeast with micro minerals effects in fat.

Referências

Associação Brasileira de Normas Técnicas – ABNT. (1993). Análise sensorial dos alimentos e bebidas: terminologia.

American meat science association - AMSA. (2001). Meat evaluation handbook. Savoy: AMSA.
American Meat Science Association - AMSA. (2015). Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of meat. Champaign: American Meat Science Association.

American meat science association - AMSA. (2016). Research guidelines for cookery, sensory evaluation and instrumental tenderness measurements of meat (2nd ed.), Champaign, Illinois, USA: AMSA.

Arvizu, R. R., Domínguez, I. A., Rubio, M. S., Bórquez, J. L., Pinos-Rodríguez, J. M., González, M., & Jaramillo, G. (2011). Effects of genotype, level of supplementation, and organic chromium on growth performance, carcass, and meat traits grazing lambs. Meat Science, 88(3), 404-408.

Association of Official Analytical Chemists - AOAC. (1995) Official methods of analysis of the Association of the Analytical Chemists. (16th ed.), Washington.

Association of Official Analytical Chemists - AOAC. (2005) Official methods of analysis. (18th ed.), Washington: AOAC International.

Bhattacharya, A., Rahman, M. M., McCarter, R., O'Shea, M., & Fernandes, G. (2006) Conjugated linoleic acid and chromium lower body weight and visceral fat mass in high-fat-diet-fed mice. Lipids, 41(5), 437-44.

Bickerstaffe, R., Le Couteur, C. E., & Morton, J. D. (1997). Consistency of tenderness in New Zealand retail meat. In: International Congress of Meat Science And Technology. Anais... 196-197.

Boleman, S. J., Boleman, S. L., Miller, R. K., Taylor, J. F., Cross, H. R., Wheeler, T. L., Koohmaraie, M., Shackelford, S. D., Miller, M. F., West, R. L., Johnson, D. D., & Savel, J. W. (1997). Consumer evaluation of beef of known categories of tenderness. Journal of Animal Science, 75(6), 1521-1524.
Bonacina, M. S., Osório, M. T. M., Osório, J. C. S., Corrêa, G. F., & Hashimoto, J. H. (2011). Influência do sexo e do sistema de terminação de cordeiros Texel × Corriedale na qualidade da carcaça e da carne. *Revista Brasileira de Zootecnia*, 40(6), 1242-1249.

Bressan, M. C., Prado, O. V., Pérez, J. R. O., Lemos, A. L. S., & Bonagurio, S. (2001). Effect of the slaughter weight on the physical-chemical characteristic of Bergamácia and Santa Inês lambs meat. *Ciência e Tecnologia de Alimentos*, 21(3), 293-303.

Cappelle, E. R., Valadares Filho, S. C., Silva, J. F. C., & Cecon, P. R. (2001). Estimativas do Valor Energético a partir de Características Químicas e Bromatológicas dos limentos. *Revista Brasileira de Zootecnia*, 30(6), 1837-1856.

Chung, Y. H., Walker, N. D., McGinn, S. M., & Beauchemin, K. A. (2011). Differing effects of 2 active dried yeast (Saccharomyces cerevisiae) strains on ruminal acidosis and methane production in non-lactating dairy cows. *Journal of Dairy Science*, 94(5), 2431-2439.

CNA Brasil. Ovinos e caprinos: balanço (2017). Retrieved from https://www.cnabrasil.org.br/assets/arquivos/ovinos_caprinos_balanco_2017.pdf.

Costa, R. G., Santos, N. M., Sousa, W. H., Queiroga, R. C. R. E., Azevedo, P. S., & Cartaxo, F. Q. (2011). Physical and sensorial quality of lamb meat of three different genotypes fed diets formulated with two roughage:concentrate ratios. *Revista Brasileira de Zootecnia*, 40(8), 1781-1787.

Costa, R. G., Lima, A. G. V. O., Oliveira, C. F. S., Azevedo, P. S., & Medeiros, A. N. (2012). Using different methodologies to determination the loin eye area in sheep. *Archivos de Zootecnia*, 61(236), 615-618.

Coutinho, M. A. S., Morais, M. G., Alves, F. V., Fernandes, H. J., Feijó, G. L. D., Ítavo, C. C. B. F., Compari, M. A. S., & Coelho, R. G. (2013). Physicochemical characteristics and centesimal composition of ewe lambs meat cuts with different ratio forage: concentrate. *Revista Brasileira de Saúde e Produção Animal*, 14(4), 660-671.
Domínguez-Vara, I. A., González-Munhoz, S. S., Pinos-Rodríguez, J. M., Bórquez-Gastelum, J. L., Bárcena-Gama, R., Mendoza-Martínez, G., Zapata, L. E., & Landois-Palencia, L. L. (2009). Effects of feeding selenium-yeast and chromium-yeast to finishing lambs on growth, carcass characteristics, and blood hormones and metabolites. *Animal Feed Science and Technology*, 152(1-2), 42-49.

FAO. FAOSTAT Production live animals. (2018). Retrieved from http://www.fao.org/faostat/en/#data/QA/visualize.

Fernandes, A. R. M., Sampaio, A. A. M., Henrique, W., Oliveira, E. A., Tullio, R. R., & Perecin, D. (2008). Carcass and meat characteristic of cattle receiving different diets in feedlot. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, 60(1), 139-147.

Fernandes, R. P. P., Freire, M. T. A., Guerra, C. C., Carrer, C. C., Balieiro, J. C. C., & Trindade, M. A. (2012). Estabilidade físico-química, microbiológica e sensorial de carne ovina embalada a vácuo estocada sob refrigeração. *Ciência Rural*, 42(4), 724-729.

Ferrão, S. P. B., Bressan, M. C., Oliveira, R. P., Pérez, J. R. O., Rodrigues, E. C., & Nogueira, D. A. (2009). Características sensoriais da carne de cordeiros da raça santa inês submetidos a diferentes dietas. *Ciênc. agrotec.*, Lavras, 33(1), 185-190.

Grandis, F. A., Ribeiro, E. L. A., Mizubuti, I. Y., Bumbieris Junior, V. H., Prado, O. P. P., & Pinto, A.P. (2016). Carcass characteristics and meat quality of lambs fed with different levels of soybean cake in replacement of soybean meal. *Ciência Animal Brasileira*, 17(3), 327-341.

Gularte, M. A., Treptow, R. O., Pouey, J. L. F., & Osorio, J. C. (2000). Meat lamb tenderness influenced by age and sex in Corriedale lineage. *Ciência Rural*, 30(3), 485-488.

Houben, J. H., Van Dijk, A., Eikelenboom, G., & Hoving-Bolink, A. H. (2000). Effect of dietary vitamin E supplementation, fat level and packaging on colour stability and lipid oxidation in minced beef. *Meat Science*, 55(3), 331–336.
Instituto Brasileiro de Geografia e Estatística – IBGE. (2018). Retrieved from https://sidra.ibge.gov.br/tabela/3939#resultado.

Jouany, J. P., Mathieu, F., Senaud, J., Bohatier, J., Bertin, G., & Mercier, M. (1998). The effect of Saccharomyces cerevisiae and Aspergillus oryzae on the digestion of the cell wall fraction of a mixed diet in defaunated and refaunated sheep rumen. *Reprod Nutr Dev.*, 38(4), 401-16.

Kneeskern, S. G., Dilger, A. C., Loerch, S. C., Shike, D. W., & Felix, T. L. (2016). Effects of chromium supplementation to feedlot steers on growth performance, insulin sensitivity, and carcass characteristics. *J Anim Sci.*, 94(1), 217-26.

Lima, L. D., Rego, F. C. A., Koetz Junior, C., Ribeiro, E. L. A., Constantino, C., Belan, L., Gasparini, M. J., Sanchez, A. F., & Zundt, M. (2013). Interferência da dieta de alto grão sobre as características da carcaça e carne de cordeiros Texel. *Semia: Ciênc. Ag.*, 34(6), 4053-4064.

Luchiari Filho, A. (2000). Pecuária da carne bovina. São Paulo.

Markowiak, P., & Ślizewka, K. (2018). The role of probiotics, prebiotics and synbiotics in animal nutrition. *Gut Pathog*, 10, 1-20.

Medeiros, L. G., Oba, A., Shimokomaki, M., Pinheiro, J. W., Silva, C. A., Soares, A. L., Pissinati, A., & Almeida, M. (2012). Desempenho, características de carcaça e qualidade de carne de frangos de corte suplementados com selênio orgânico. *Semia: Ciências Agrárias*. 33(2), 3361-3369.

Mizubuti, I. Y., Pinto, A. P., Ramos, B. M. O., & Pereira, E. S. (2009). Métodos laboratoriais de avaliação de alimentos para animais. Londrina: Eduel.

Mottran, D. S. (1998). Flavour formation in meat and meat products: a review. *Food Chemistry*, 62(4), 415-424.
National Research Council -NRC. (2007). Nutrient requirements of small ruminants: sheep, goats, cervids, and new world camelids. Washington, D.C.: National Academy Press.

Osório, M. T. M., Jardim, P. O., Osório, C., Osório, M., Jardim, P., Osorio, J., Osório, M., Osório, J., Osorio-Keese, M., Jardim, P. C. B. V., Osorio, R. A. L., & Osório, J. C. S. (1998). Métodos para avaliação da produção de carne ovina: in vivo, na carcaça e na carne. UFPel Press, Pelotas.

Osório, J. C. S., & Osório, M. T. M. (2005). Produção de carne ovina. Técnicas de avaliação in vivo e na carcaça. 2nd. UFPel Press, Pelotas.

Osório, J. C. S., Osório, M. T., & Sañudo, C. (2009). Sensorial characteristics of sheep meat. Revista Brasileira de Zootecnia, 38(SE), 292-300.

Pinheiro, R. S. B., Sobrinho, A. G. S., & Yamamoto, S. M. (2007). Performance of lambs receiving probiotics in creep feeding. Archives of Veterinary Science, 11(3), 38-42.

Pikul, J., Leszcynski, D. E., & Kummerow, F. A. (1989). Evaluation of tree modified TBA methods for measuring lipid oxidation in chickens meat. Journal of Agriculture and Food Chemistry, 37(5), 1309-1313.

Quin, S., Gao, J., & Huang. K. (2007). Effects of different selenium sources on tissue selenium concentrations, blood GSH-Px activities and plasma interleukin levels in finishing lambs. Biological Trace Elem Research, 116(1), 91-102.

Rosa, G. T., Pires, C. C., Silva, J. H. S., Motta, O. S., & Colomé, L. M. (2008). Composição tecidual da carcaça e de seus cortes e crescimento alométrico do osso, músculo e gordura da carcaça de cordeiros da raça texel. Acta Scientiarum. Animal Sciences, 24(4), 1107-1111.

Rego, F. C. A., Lima, L. D., Baise, J., Gasparini, M. J., Eleodoro, J. I., Santos, M. D., & Zundt, M. (2019). Desempenho, características da carcaça e da carne de cordeiros confinados com níveis crescentes de bagaço de laranja em substituição ao milho. R. Cienc. anim. bras., 20(1-12), 50159.
Rego, F. C. A., Françozo, M. C., Ludovico, A., Castro, F. A. B., Zundt, M., Lupo, C. R., Belan, L. Cunha Filho, L. F. C., Santos, J. S., & Castilho, C. (2017). Fatty acid profile and lambs’ meat quality fed with different levels of crude glycerin replacing corn. *Semina-Ciencias Agrarias*, 38(4), 2051.

Santos, C. P., Ferreira, A. C. D., Valença, R. L., Silva, B. C. D., Bomfim, L. E. L. M., & Silva, M. C. (2015). Live weight components and characteristics meat of lamb foods with silage of orange. *Archives of Veterinary Science*, 19(3), 21-29.

Sañudo, C., Alfonso, M., Sánches, A., Delfa, R., & Teixeira, A. (2000). Carcass and meat quality in light lambs from different fat classes in the EU carcass classification system. *Meat Science*, 56, 89-94.

Schofield, B. J., Lachner, N., Le, O. T., McNeill, D. M., Dart, P., Ouwerkerk, D., Hugenholtz, P., & Klieve, A. V. (2018). Beneficial changes in rumen bacterial community profile in sheep and dairy calves as a result of feeding the probiotic Bacillus amyloliquefaciens H57. *J Appl Microbiol*, 124(3), 855-866.

Silberberg, M., Chaucheyras-Durand, F., Commun, L. (2013). Repeated acidosis challenges and live yeast supplementation shape rumen microbiota and fermentations and modulate inflammatory status in sheep. *Animal*, 7(12), 1910–1920.

Silva, D. J., & Queiroz, A. C. (2002). Análise de alimentos: métodos químicos e biológicos. UVF Press, Viçosa.

Silva, J. S., Rodriguez, F. D., Trettel, M., Abal, R. T., Lima, C. G., Yoshikawa, C. Y. C., & Zanetti, M. A. (2020). Performance, carcass characteristics and meat quality of Nellore cattle supplemented with supranutritional doses of sodium selenite or selenium-enriched yeast. *Animal*, 14(1), 215-222.

Signorini, M. L., Soto, L. P., Zbrun, M. V., Sequeira, G. J., Rosmini, M. R., & Frizzo, L. S. (2012). Impact of probiotic administration on the health and fecal microbiota of young calves: A meta-analysis of randomized controlled trials of lactic acid bacteria. *Research in Veterinary Science*. 
Sobrinho, A. G. S., Purchas, R. W., Kadim, I. T., & Yamamoto, S. M. (2005). Meat quality in lambs of different genotypes and ages at slaughter. *Revista Brasileira de Zootecnia*, 34(3), 1070-1078.

Soldá, N. M., Glombowsky, P., Rosseto, L., Tomasi, T., Santin Junior, I. A., Zampar, A., Silva, A. S., & Cucco, D. C. (2020). Diferentes fontes de selênio adicionado a dieta de grão de milho inteiro na fase de terminação de novilhos Angus. *Research, Society and Development*. 9(8), e320984997.

Souza, X. R., Bressan, M. C., Pérez, J. R. O., Faria, P. B., Vieira, J. O., & Kabeya, D. M. (2004). Effects of breed group, gender and slaughter weight group on the physical-chemical parameter of the growing lambs. *Food Science and Technology*, 24(4), 543-549.

Terra, N. N., Cichoski, A. J., & Sossela, R. J. F. (2006). Values of nitrite and TBARS along the process and storage of cured, ripened and fermented pig shoulders. *Ciência Rural*, 36(3), 965-970.

Torres, E. A. F. S., & Okani, E. T. (1997). Teste de TBA: ranço em alimentos. *Revista Nacional da Carne*, 243, 68-76.

Uyeno, Y., Shigemori, S., & Shimosato T. (2015). Effect of Probiotics/Prebiotics on Cattle Health and Prod

**Percentage of contribution of each author in the manuscript**

- Leticia Jalloul Guimarães – 12,5%
- Lucas Ferreira Santiago – 12,5%
- Juliana Pampana Nicolau – 12,5%
- Fabiola Cristine de Almeida Rego – 12,5%
- Calie Castilho – 12,5%
- Luiz Fernando Cunha Filho – 12,5%
- Francine Mezzomo Giotto – 12,5%
- Marilice Zundt – 12,5%