

Physicochemical properties and sensory evaluation of meat from feedlot lambs fed with wet brewery waste

Propriedades físico-químicas e avaliação sensorial da carne de cordeiros confinados alimentados com resíduo úmido de cervejaria

Propiedades fisicoquímicas y evaluación sensorial de la carne de corderos de corral alimentados con granos húmedos de cerveza

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Abstract

Sheep meat presents variations in qualitative characteristics that influence consumer preference. These characteristics are influenced by ante-mortem factors, such as sex, breed, age at slaughter and feeding; and post-mortem factors, such as meat cooling and storage time and temperature. Twenty-four uncastrated Suffolk lambs were housed in individual corrals and received one of four treatments consisting of four levels of replacement of sorghum silage with wet brewery waste (WBW; 0; 33; 66 and 100% replacement). The diets were isoproteic and contained 18.8% crude protein. The weight and fat proportion in the carcass increased linearly ($p \leq 0.05$) while the muscle proportion decreased linearly ($p \leq 0.05$) as the WBW levels were increased in the diets. The proximate composition of the meat was not significantly influenced by the WBW levels ($P > 0.05$), except for the ash content which increased linearly ($p = 0.0003$). There was no influence ($p > 0.05$) of the use of WBW on pH, cooking losses and lambs' meat texture profile. Shear force decreased linearly ($p \leq 0.05$). Regarding the meat color, lightness (L^*) and redness (a^*) were not influenced by the inclusion of WBW. Yellowness (b^*) increased linearly ($p = 0.0038$). Regarding the attributes related to lambs' sensory analysis, there was no effect ($p > 0.05$) of the inclusion of WBW in the diets. The use of WBW as a

bulky food replacing sorghum silage in confined feedlot lambs diet allows the main physical-chemical characteristics related to meat quality to be kept in the normal standards obtained for ovine species.

Keywords: Alternative food; Lamb meat; Ruminants; Agro-industry by-products.

Resumo

A carne ovina apresenta variações nas características qualitativas que influenciam na preferência dos consumidores. Essas características são influenciadas por fatores ante mortem, como sexo, raça, idade de abate e alimentação; e fatores post mortem, como tempo e temperatura de resfriamento e armazenamento da carne. Vinte e quatro cordeiros machos Suffolk não castrados foram alojados em currais individuais e receberam um dos quatro tratamentos constituídos por quatro níveis de substituição da silagem de sorgo por resíduo úmido de cervejaria (RUC; 0; 33; 66 e 100% de substituição). As dietas foram isoproteicas e continham 18,8% de proteína bruta. Em relação a carcaça, o peso e a proporção de gordura aumentaram linearmente ($p \leq 0.05$) enquanto a proporção muscular diminuiu linearmente ($p \leq 0.05$) conforme o incremento de RUC na dieta. A composição química da carne dos cordeiros não foi influenciada pelos níveis de RUC ($p > 0.05$), exceto para o teor de cinzas que apresentou um comportamento linear crescente ($p = 0.0003$). Não houve influência ($p > 0.05$) do uso de RUC sobre o pH, perdas por cozimento e perfil de textura da carne de cordeiros. A força de cisalhamento diminuiu linearmente ($p \leq 0.05$). Em relação à cor da carne, a luminosidade (L^*) e intensidade de vermelho (a^*) não foram influenciadas pela inclusão de RUC. Intensidade de amarelo (b^*) aumentou linearmente ($p = 0.0038$). Em relação aos atributos relacionados à análise sensorial da carne dos cordeiros, não houve efeito ($p > 0.05$) da inclusão do RUC nas dietas. A utilização do RUC como alimento volumoso em substituição à silagem de sorgo na dieta de ovinos permite que as principais características físico-químicas relacionadas à qualidade da carne sejam mantidas nos padrões de normalidade obtidos para cordeiros.

Palavras-chave: Alimentos alternativos; Carne de cordeiro; Ruminantes; Subprodutos da agroindústria.

Resumen

La carne ovina presenta variaciones en las características cualitativas que influyen en la preferencia del consumidor. Estas características están influenciadas por factores ante-mortem, como el sexo, la raza, la edad de faena y la alimentación; y factores post mortem, como el tiempo y temperatura de enfriamiento y almacenamiento de la carne. Veinticuatro corderos Suffolk machos no castrados se alojaron en corrales individuales y recibieron uno de cuatro tratamientos que consistían en cuatro niveles de reemplazo de ensilaje de sorgo con residuos húmedos de cervecería (RHC; 0; 33; 66 y 100% de reemplazo). Las dietas fueron isoproteicas y contenían 18,8% de proteína cruda. Con relación a la canal, el peso y la proporción de grasa aumentaron linealmente ($p \leq 0,05$) mientras que la proporción muscular disminuyó linealmente ($p \leq 0,05$) conforme aumentó la RHC en la dieta. La composición química de la carne de cordero no fue influenciada por los niveles de RHC ($p > 0.05$), excepto por el contenido de cenizas, que mostró un comportamiento lineal creciente ($p = 0.0003$). No hubo influencia ($p > 0.05$) del uso de RHC sobre el pH, las pérdidas por cocción y el perfil de textura de la carne de cordero. La fuerza de cizallamiento disminuyó linealmente ($p \leq 0.05$). En cuanto al color de la carne, la luminosidad (L^*) y la intensidad del rojo (a^*) no se vieron influenciadas por la inclusión de RHC. La intensidad del amarillo (b^*) aumentó linealmente ($p = 0.0038$). En cuanto a los atributos relacionados con el análisis sensorial de la carne de cordero, no hubo efecto ($p > 0.05$) de la inclusión de RHC en las dietas. El uso de RHC como forraje para reemplazar el ensilaje de sorgo en la dieta de los ovinos permite mantener las principales características físicoquímicas relacionadas con la calidad de la carne en los estándares de normalidad obtenidos para los corderos.

Palabras clave: Alimentos alternativos; Carne de cordero; Rumiantes; Subproductos agroindustriales.

1. Introduction

Lamb production is a good option when searching for excellent nutritional meat quality, once the animals are slaughtered earlier, with the coloration of pink meat, high yield in carcass (45 to 60%) and intramuscular fat estimated that a threshold of 4–5% (Hopkins, et al., 2006). In addition to being highly valuable in essential nutrients such as iron, selenium, zinc, copper and manganese, its lipid content also provides energy, essential fatty acids, and fat-soluble vitamins (Cabrera & Saadoun, 2014).

Meat quality is a combination of the attributes flavor, juiciness, texture, tenderness, and appearance, associated with a low-fat and very muscular carcass (Silva Sobrinho, 2001). According to Zapata (2000), among the consumers, the most important quality attributes are the color of the meat, its capacity of water retention, as well as its tenderness and juiciness. The breed of the animal and the feeding system may influence some of the quality characteristics, as well as the age they are sent to slaughter.

Due to the previous diet offered to the lamb, the quality of the meat undergoes a series of changes in its attributes, which reflect on the flavor and consequently on the acceptance of the product (Mandolesi, et al., 2020). Worldwide, most lamb are finished in extensive systems with forage-based diets (i Furnols, et al., 2006), but due to the reduction in the size of areas destined for animal production (Halmemies-Beauchet-Filleau, et al. al., 2018), intensive production systems are increasingly being used. However, regardless of the changes in carcass and meat characteristics, the reality is that the profitability of intensive systems remains low due to high production costs, especially for food (Benoit, et al., 2019).

The use of alternative foods in the diet of ruminants in confinement becomes viable when they have good nutritional value, good production rates and the cost of these foods compared to traditional foods (Halmemies-Beauchet-Filleau et al., 2018). Also, according Halmemies-Beauchet-Filleau, et al. (2018) the use agro-industrial by-products as a food source for ruminants are increasingly common due to the need to reduce production costs to make better use of local products, as well as helping against reduction environmental contamination. Wet brewery waste (WBW) is a by-product of brewing industry and has a high nutritional quality and great potential for animal feeding. According to Geron, et al. (2008), wet brewery waste is a by-product with high protein content (between 17 and 32%), high neutral detergent fiber (NDF between 55 and 65%), total carbohydrates (TC) and ethereal extract (EE), which makes it an interesting product to be used to feed animals as both bulk and concentrate. The use of WBW in ruminant feeding has been evaluated in several studies, however, most of them address the animal performance without approaching the qualitative aspects of sheep meat, which is a necessity, considering the marked influence of diet on these characteristics.

The aim of the present study was to evaluate the physicochemical and sensory properties of lamb meat fed with wet brewery waste.

2. Methodology

2.1 Location, animals and feeding management

This study was carried out at the Sheep Laboratory of the Department Animal Science of the Federal University of Santa Maria, located in Santa Maria - RS, Brazil, after approval by the Ethics Committee on Animal Use of the same institution (approval n°. 037-2014). Twenty-four Suffolk non-castrated lambs, from single parturition were weaned with an average age of 60 days with an average live weight of 30 kg. The lambs were allocated to individual stalls (2 m² each) within a shelter, with rice hull bedding, and equipped with individual feeders and drinking fountains. The animals were allocated in a complete randomized experimental design (CRD) with four treatments, constituted by different levels of substitution of roughage (sorghum silage) by WBW (0%; 33%; 66% and 100% of substitution) and six repetitions.

The lambs were weighted and assessed by condition score (scale of 1.0 to 5.0 with 0.25-point intervals, where 1.0 = emaciated and 5.0 = excessively fat) at the beginning of the experiment, and every 14 days with an 18 h fasting (Osório, et al., 1998). The experiment started after 10 days of adaptation (facilities, feeding and handling conditions).

The WBW used on the present study was acquired in a brewing agribusiness in Santa Maria and was preserved as silage. The diets were isonitrogenous and formulated according to NRC (2007) to obtain 200 g of daily weight gain. Animals were fed ad libitum (15% leftovers) offering equal quantities at 08:00 h and 17:00 h. The ration (50:50 roughage: concentrate ratio, on dry matter basis) combined a concentrate (ground corn, soybean meal and mineral mixture) and the roughage, according to the experimental treatment (sorghum silage and WBW; previously published in Frasson, et al., 2018). Upon reaching a body condition score of 3.0 (range of variation from 30 to 70 days between animal), the lambs were slaughtered, and the carcasses were refrigerated at 2°C for 24 h.

2.2 Chemical composition and meat pH

Immediately after chilling, the carcass was sectioned longitudinally and the *Longissimus dorsi* muscle removed. This was sectioned, with each portion destined for analysis as per Cañeque & Sañudo (2005).

The meat pH was measured 24 hours after slaughtering using a digital pHmetre (Hanna model HI99163) coupled with a penetration electrode. Measurements were taken on the *Longissimus dorsi* muscle between the 12th and 13th ribs.

After 24 hours, the right shoulder was dissected in bone, muscle, fat and other tissues (bones and fat, such as ganglia, fascia, tendons and large vessels). After separation, each of the tissues was weighed in an electronic scale, and its proportion to the shoulder was calculated (Osório & Osório, 2005).

A part of the *Longissimus dorsi* muscle was lyophilized for later determination of the centesimal composition of the meat (moisture, crude protein, total lipids, and mineral matter) according to AOAC standard methods (1990). The intramuscular fat was extracted according to Hara & Radin (1978).

2.3 Instrumental measurement of meat

Longissimus dorsi color was determined using a previously calibrated colorimeter (Minolta Chroma Meter CR-300; Minolta Camera Co. Ltd., Osaka, Japan) with a D65 illuminant. Results were expressed as L* (lightness), a* (red intensity) and b* (yellow intensity) coordinates.

To determine the cooking losses (LC) a part of the *Longissimus dorsi* was used, which comprises the last dorsal vertebrae following the methodology proposed by Felício, (1999). Losses were expressed as a percentage in relation to the weight of the raw meat sample. From the same part that the cooking losses were determined, the Instrumental Texture Profile (Texture Profile Analysis - TPA) was also determined using an appropriate texture analyzer (TA-XT.plus) with a 36-mm-diameter P/36R metal probe. Data were measured using Texture Expert Exponent software (Stable Micro Systems Ltd., Surrey, England) following the methodology proposed by de Huidobro, Miguel, Blazquez & Onega (2005). Shear force was also evaluated using the aforementioned texturometer Texture Analyser (TA-XT.plus) operating with a Warner-Bratzler Shear Force blade at 20 cm/min, which measured the maximum force required to break the muscle fibers, with results expressed in kg F-cm³ following the methodology proposed by Cross, West & Duntson (1981).

2.4 Sensory evaluation of lamb meat

The sensory evaluation of lamb meat was carried out with the aid of eight trained judges who used a 9-points unstructured scale to evaluate the following sensory attributes: characteristic aroma, strange aroma, characteristic taste, porklike taste, metallic taste, rancid taste, acidic taste, sweetish taste, fat-like taste, tenderness, and juiciness. These attributes were previously raised in a training session with the team of judges with five years of experience. An incomplete balanced block design was used, according to Cochran & Cox (1992) recommendations in which all panelists evaluate all treatments of the study. The order of presentation was balanced so that each treatment was presented in equal number of times in each position, thus controlling the effects of first order and carry-over, according to Macfie, Bratchell, Greenhoff and Vallis (1989).

2.5 Statistical analysis

Results were analyzed according to a completely randomized experimental design with four experimental diets and six repetitions. Analysis of Variance and Regression Analysis were performed using SAS statistical package (SAS Version 8.0, SAS Institute Inc. Cary, NC, USA). Differences among treatment means were declared whenever $p \leq 0.05$.

3. Results and Discussion

The shoulder tissue composition showed (Table 1) difference only for muscle and fat content. Muscle content decreased linearly ($p \leq 0.05$) and consequently, there was a significant increase ($p \leq 0.05$) in the proportion of fat according to the increase of WBW in the diet. This result can be explained by the increase in energy content (previously published in Frasson, et al., 2018) of the diet due to the WBW higher participation. In addition, there was also a reduction in the proportion of acid detergent fiber from diets with WBW increase, which contributed to a better digestibility and nutrient utilization of the diet, which resulted in an improvement in the finishing degree and an increase in the proportion of fat (mainly subcutaneous fat) present in the animal carcass. According to Osório, et al. (2012), the average of total fat in carcass of a sheep in a body condition scoring 3 at the time of slaughter is 19.1% and all the results obtained in the present study were lower than this value.

Table 1. Average values for weight (kg) and proportion (%) of the different tissues that make up the lambs' shoulders, according to the experimental rations

	Percentage of wet brewery waste				Regression equation	R ²	Pr>F
	0	33	66	100			
Shoulder (kg)	1.5±0.2	1.6±0.2	1.7±0.2	1.6±0.2	= 1.58	-----	0.279
Muscle (%)	55.9±2.2	55.1±1.1	54.2±2.1	53.8±2.5	¹	0.16	0.05
Bone (%)	19.5±1.8	19.0±0.7	18.3±1.4	18.6±1.1	= 18.87	-----	0.16
Fat (%)	15.4±2.5	17.3±1.1	18.9±3.3	18.5±3.9	²	0.20	0.05
Others (%)	9.1±1.6	8.5±0.8	8.6±1.0	9.0±1.2	= 8.81	-----	0.95
Muscle:Bone	2.9±0.3	2.9±0.1	2.9±0.2	2.9±0.2	= 2.91	-----	0.85
Muscle:Fat	3.7±0.6	3.2±0.2	3.0±0.7	3.0±0.9	= 3.23	-----	0.09

¹ $\hat{Y} = 55.85489 - 0.02171 \times \text{WBW}$. ² $\hat{Y} = 15.91945 + 0.03245 \times \text{WBW}$. Source: Authors.

The chemical composition analysis of meat showed no statistical differences between the examined groups except for ash content ($p=0.0003$; Table 2). The ash analysis provides previous information on the nutritional value of the food ingested, regarding its content in minerals, which is also called mineral matter. Sorghum silage presented smaller amounts of ash compared to the WBW (Frasson, et al., 2018). Thus, lower ash content could be observed in the meat of animals that did not receive or received lower amounts of WBW (Table 2). The supplied WBW increased intake of minerals by the animals and consequently increased the mineral matter content in the meat. The chemical composition of sheep meat in this study is similar to the nutrient data base of the United States Department of Agriculture (United States, 2018) for raw lamb meat (Nº. 17026), where the following values are reported: 72.6 % moisture, 20.9% protein and 5.94% total lipids and 1.06% ash.

Table 2. Chemical composition (%) of *Longissimus dorsi* muscle.

	Percentage of wet brewery waste				Regression equation	Pr>F
	0	33	66	100		
Moisture	75.7±0.5	76.2±1.3	75.6±0.5	75.6±0.6	= 75.78	0.51
Protein	17.2±1.9	15.3±1.2	17.8±2.2	17.9±1.7	= 17.05	0.22
Fat	4.3±1.5	3.4±1.7	3.6±0.8	3.4±1	= 3.68	0.31
Ash	0.8±0.1	0.9±0.1	1.0±0.1	1.10±0.1	¹	0.0003

¹ $\hat{Y} = 0.83686 + 0.00244 \times \text{WBW}$. Source: Authors.

The instrumental analysis of meat, such as cooking loss (CL) and pH showed no difference between the treatments, except for the shear force (SF) ($p \leq 0.05$; Table 3), presenting lower values for treatments that had more WBW in the diet. The pH value analysis measured 24 hours after slaughter showed that the glycolysis process proceeded correctly in both groups (Table 3). Generally, the pH of the sheep meat declines from seven upon slaughter to reach approximately 5.3–5.8 at 24 h (Savell, Mueller & Baird, 2005).

The mean value obtained in the shear force of *Longissimus dorsi* muscle was 3.5 kgf for the animals that received only WBW and 4.7 kgf for the animals that received only sorghum silage. Belew, et al. (2003) classified meat as very tender (less than 3.2 kgf), soft (between 3.2 and 3.9 kgf), intermediate softness (between 3.9 and 4.6 kgf) and hard (above 4.6 kgf). Thus, according to this classification, the meat from animals of this research can be considered soft for animals fed WBW. Intramuscular fat may be the main reason for these different results (Angood, et al., 2008).

Table 3. Cooking loss (CL), shear force (SF), texture profile analysis (TPA) and pH, expressed in absolute and relative values, in the *Longissimus dorsi* muscle of lambs fed according for the experimental rations.

	Percentage of wet brewery waste				Regression equation	R ²	Pr>F
	0	33	66	100			
CL, %	24.8±4.2	23.6±5.9	20.4±6.8	21.3±7.2	=22.5	---	0.22
SF, Kgf/cm ²	4.7±0.7	3.8±1.3	3.3±1.3	3.5±0.8	¹	0.23	0.05
pH 24 hours	5.9±0.14	5.9±0.12	5.9±0.06	5.8±0.17	=5.9	---	0.19
Texture profile analysis							
Cohesiveness ^a	0.4±0.04	0.4±0.04	0.4±0.03	0.4±0.03	=0.43	---	0.23
Springiness (cm)	1.0±0.07	0.9±0.05	0.9±0.04	0.9±0.14	=0.97	---	0.50
Chewiness ^b	104.8±23	86.3±22.3	92±21.3	84.5±29	=92.2	---	0.20
Toughness (N)	226.9±32.7	204.9±28.2	215.5±30.3	198±33	=211.8	---	0.19

^aNon-dimensional; ^bIn N/cm. ¹ $\hat{Y} = 4.45532 - 0.01231 \times \text{WBW}$. Source: Authors.

The *Longissimus dorsi* muscle color, the variables L*, a* showed no differences between treatments, except for b*, which showed a significant difference ($p=0.0038$; Table 4). Zeola, et al. (2011) state that values between 31.36 and 38.0 for L*, 12.27 and 18.01 for a* and 3.34 to 5.65 for b* are considered normal for sheep meat. The mean values observed for all parameters in the present experiment are close to the values found by Zeola, et al. (2011), only b* is above the values described. According to Sañudo, et al. (1997), the value of b* corresponds to the yellow content that is normally influenced by the presence of beta-carotene in fat. The content of carotenoids in animal tissues and products is highly dependent on the diet provided. In the present study, the highest value of b* of the *Longissimus dorsi* muscle was observed in lambs that received WBW and ground corn in the diet. This result can be explained because maize is a carotenogenic plant (Rodriguez, 2001) and the carotenoids in corn grain are classified into carotenes (β -caroteno e α -caroteno) and xanthophylls (lutein, zeaxanthin and β -criptoxanthin), with higher concentrations of lutein and zeaxanthin compared to other carotenoids (Kurilich & Juvik, 1999). In addition, plant oils found in malt contain essential fatty acids and significant levels of other bioactive compounds, such as tocopherols, phytosterols and carotenoids that have antioxidant effects that protect the biomolecules from the action of free radicals (Arranz, et al., 2008).

Table 4. Lightness (L*), red intensity (a*) and yellow intensity (b*) of the *Longissimus dorsi* of lambs fed according for the experimental rations.

	Percentage of wet brewery waste				Regression equation	R ²	Pr>F
	0	33	66	100			
L*(A)	40.4±2.4	41.3±3.0	41.5±2.6	40.8±2.2	= 40.98	-----	0.7602
a*(A)	14.7±2.1	14.9±3.0	15.5±2.3	16.7±2.4	=15.47	-----	0.1468
b*(A)	11.3±1.5	11.5±0.8	12.7±1.6	13.5±1.4	¹	0.339	0.0038

$$^1\hat{Y} = 11.08031 + 0.02371 \times \text{WBW}. \text{ Source: Authors.}$$

The sensory evaluation of lamb meat showed no difference in any of the evaluated attributes between the treatments (Table 5). Regardless of the WBW content in the diet, there was a higher concentration of aroma-related values (5.16 on a scale from 1 to 9) as characteristic of sheep meat, with a small proportion of foreign flavor identified by panelists. Thus, it can be stated that the use of up to 50% of WBW in the DM of the diet of feedlot lambs does not cause negative changes in the aroma and taste of meat produced from those animals, an important aspect in relation to the acceptance of this product by the consumer market.

Table 5. Sensory analysis results of feedlot lambs with different levels of inclusion of WBW as roughage.

Parameters*	Percentage of wet brewery waste				Regression equation	Pr>F
	0	33	66	100		
Odour						
Characteristic	5.0±2.1	5.1±1.8	5.3±2.6	5.2±2.0	= 5.1	0.79
Weird	1.7±1.9	1.6±1.9	1.6±1.6	1.5±1.5	= 1.6	0.85
Flavor						
Characteristic	4.6±1.7	4.8±1.9	5.0±2.1	4.5±1.6	= 4.8	0.93
Liver	1.3±1.5	0.9±0.8	1.5±1.3	0.8±0.7	= 1.1	0.64
Metal	1.2±0.9	1.4±1.3	1.3±1.3	1.7±1.5	= 1.4	0.52
Rancid	0.4±0.6	0.4±0.6	0.5±0.6	0.4±0.5	= 0.4	0.97
Acid	1.0±1.2	0.8±0.9	1.0±1.0	1.1±1.1	= 1.0	0.70
Swine meat	0.7±0.9	0.6±0.7	1.4±1.5	0.8±1.0	= 0.9	0.51
Sweetly	0.8±0.8	0.6±0.6	0.7±0.9	0.7±0.6	= 0.7	0.88
Greasy	2.4±1.7	2.3±1.4	1.9±1.2	2.9±1.6	= 2.4	0.62
Texture						
Tenderness	6.2±1.4	6.4±1.3	7.4±1.0	6.8±1.4	= 6.7	0.17
Juiciness	4.9±1.4	5.1±1.8	4.8±1.8	5.5±1.4	= 5.1	0.56

*Lower notes approached the low end (zero): indicate meats with no characteristic aroma, no characteristic flavor, tougher meat and less juiciness. Higher notes approached the high end (nine): indicate meats with a stronger characteristic aroma, stronger characteristic flavor, softer and more juicy flesh. Source: Authors.

Regarding the tenderness of the meat, regardless of the WBW content, it was classified as very tender (average value of 6.72 on a scale from 0 to 9 where 0 is classified as very tough and 9 very tender), remaining above average in the hedonic scale. The result agrees with the results of shear force using the texturometer found in this present study (average value of 3.84 kgf/cm²; Table 3) classified as soft. It is also noteworthy that the meat of the animals showed a good result in terms of juiciness (average value of 5.1 on a scale from 0 to 9; Table 5), which, associated with tenderness, are the main attributes related to the

texture of the meat. This fact indicates that the meat from lambs fed WBW meets consumer demands.

4. Conclusion

The addition of WBW as a bulky food as a substitute of sorghum silage in feeding of lambs in confinement did not influence negatively influence the characteristics related to the lamb quality traits and meets the requirements of the consumers. It is recommended to include the wet brewery waste up to the proportion of 50% of the total dry matter of the diet. Future studies could be developed focused on the nutritional quality of the foods studied, such as dry matter digestibility, as well as ruminal parameters such as volatile fatty acids and ammoniacal nitrogen.

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References

- Angood, K. M., Wood, J. D., Nute, G. R., Whittington, F. M., Hughes, S. I., & Sheard, P. R. (2008). A comparison of organic and conventionally-produced lamb purchased from three major UK supermarkets: Price, eating quality and fatty acid composition. *Meat Science*, 78(3), 176-184. doi:10.1016/j.meatsci.2007.06.002
- AOAC. Official method of analysis. (1990). *Association of Official Analytical Chemistry*. 16th edition, Ed. By Hoorwitz, N., P. Chialo, y H. Reynold, Washington, USA.
- Arranz, S., Cert, R., Pérez-Jiménez, J., Cert, A., & Saura-Calixto, F. (2008). Comparison between free radical scavenging capacity and oxidative stability of nut oils. *Food Chemistry*, 110(4), 985-990. doi:10.1016/j.foodchem.2008.03.021
- Belew, J. B., Brooks, J. C., McKenna, D. R., & Savell, J. W. (2003). Warner–Bratzler shear evaluations of 40 bovine muscles. *Meat science*, 64(4), 507-512. doi:10.1016/S0309-1740(02)00242-5
- Benoit, M., Sabatier, R., Lasseur, J., Creighton, P., & Dumont, B. (2019). Optimising economic and environmental performances of sheep-meat farms does not fully fit with the meat industry demands. *Agronomy for sustainable development*, 39(4), 1-11. doi:10.1007/s13593-019-0588-9
- Cabrera, M. C., & Saadoun, A. (2014). An overview of the nutritional value of beef and lamb meat from South America. *Meat science*, 98(3), 435-444. doi:10.1016/j.meatsci.2014.06.033
- Cañeque, V. & Sañudo, C. (2005). *Estandarización de las metodologías para evaluar la calidad del producto (animal vivo, canal, carne y grasa) en los rumiantes*. Madrid: Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA).
- Cochran, W. G. & Cox, G. M. (1992). *Experimental designs*. 2ed. New York: John Wiley & Sons, Inc.
- Cross, H. R., West, R. L., & Dutson, T. R. (1981). Comparison of methods for measuring sarcomere length in beef semitendinosus muscle. *Meat science*, 5(4), 261-266. doi: 10.1016/0309-1740(81)90016-4
- De Huidobro, F. R., Miguel, E., Blázquez, B., & Onega, E. (2005). A comparison between two methods (Warner–Bratzler and texture profile analysis) for testing either raw meat or cooked meat. *Meat science*, 69(3), 527-536. doi:10.1016/j.meatsci.2004.09.008
- Felício, P. E. (1999). *Beef quality: Physical and organoleptic characteristics*. In: *Annual Meeting of the Brazilian Society of Animal Science*. Porto Alegre. Proceedings of the symposium and workshop. 36, 89 –97.
- Frasson, M. F., Carvalho, S., Jaurena, G., Menegon, A. M., Severo, M. M., Da Motta, J. H., & Teixeira, W. S. (2018). Intake and performance of lambs finished in feedlot with wet brewer’s grains. *Journal of Animal Science and Technology*, 60(1), 1-5. doi:10.1186/s40781-018-0166-8
- Geron, L. J. V., Zeoula, L. M., Erkel, J. A., Prado, I. N. D., Jonker, R. C., & Guimarães, K. C. (2008). Coeficiente de digestibilidade e características ruminais de bovinos alimentados com rações contendo resíduo de cervejaria fermentado. *Revista Brasileira de Zootecnia*, 37(9), 1685-1695. doi: 10.1590/S1516-35982008000900023
- Halmemies-Beauchet-Filleau, A., Rinne, M., Lamminen, M., Mapato, C., Ampapon, T., Wanapat, M., & Vanhatalo, A. (2018). Alternative and novel feeds for ruminants: nutritive value, product quality and environmental aspects. *Animal*, 12(s2), s295-s309. doi:10.1017/S1751731118002252

- Hara, A., & Radin, N. S. (1978). Lipid extraction of tissues with a low-toxicity solvent. *Analytical biochemistry*, 90(1), 420-426. doi:10.1016/0003-2697(78)90046-5
- Hopkins, D. L., Hegarty, R. S., Walker, P. J., & Pethick, D. W. (2006). Relationship between animal age, intramuscular fat, cooking loss, pH, shear force and eating quality of aged meat from sheep. *Australian Journal of Experimental Agriculture*, 46(7), 879-884. doi:10.1071/EA05311
- i Furnols, M. F., San Julián, R., Guerrero, L., Sañudo, C., Campo, M. M., Olleta, J. L., ... & Montossi, F. (2006). Acceptability of lamb meat from different producing systems and ageing time to German, Spanish and British consumers. *Meat Science*, 72(3), 545-554. doi:10.1016/j.meatsci.2005.09.002
- Kurilich, A. C., & Juvik, J. A. (1999). Quantification of Carotenoid and Tocopherol Antioxidants in *Zea mays*. *Journal of Agricultural and Food Chemistry*, 47(5), 1948-1955. doi:10.1021/jf981029d
- MacFie, H. J., Bratchell, N., Greenhoff, K., & Vallis, L. V. (1989). Designs to balance the effect of order of presentation and first-order carry-over effects in hall tests. *Journal of sensory studies*, 4(2), 129-148. doi:10.1111/j.1745-459X.1989.tb00463.x
- Mandolesi, S., Naspetti, S., Arsenos, G., Caramelle-Holtz, E., Latvala, T., Martin-Collado, D., ... & Zanolli, R. (2020). Motivations and barriers for sheep and goat meat consumption in Europe: A means-end chain study. *Animals*, 10(6), 1105. doi:10.3390/ani10061105
- NRC - National Research Council. (2007). *Nutrient Requirements of Small Ruminants: sheep, goats, cervids, and new worlds camelids*. Washington, DC: Natl. Acad. Press.
- Osório, J. C. S., et al. (1998). *Produção de carne ovina, alternativa para o Rio Grande do Sul*. Editora Universitária/UFPEL. Pelotas, Brasil.
- Osório, J. C. S. & Osório, M. T. M. (2005). *Produção de carne ovina: Técnicas de avaliação "in vivo" e na carcaça*. 2. ed. Pelotas: Ed. Universitária, UFPEL. 82 p.
- Osório, J. C. D. S., Osório, M. T. M., Fernandes, A. R. M., Seno, L. D. O., Ricardo, H. D. A., Rossini, F. C., & Orrico Junior, M. A. P. (2012). Critérios para abate do animal e a qualidade da carne. *Revista Agrarian*, 5(18), 433-443. doi:10.30612/AGRARIAN.V5I18.1822
- Rodríguez-Amaya, D. B. (2001). *A Guide to Carotenoid Analysis in Foods*. ILSI Press, International Life Sciences Institute, One Thomas Circle, NW Washington, DC.
- Sañudo, C., Campo, M. M., Sierra, I., María, G. A., Olleta, J. L., & Santolaria, P. (1997). Breed effect on carcass and meat quality of suckling lambs. *Meat Science*, 46(4), 357-365. doi:10.1016/S0309-1740(97)00030-2
- Savell, J. W., Mueller, S. L., & Baird, B. E. (2005). The chilling of carcasses. *Meat science*, 70(3), 449-459. doi:10.1016/j.meatsci.2004.06.027
- Silva Sobrinho, A. G. (2001). *Criação de ovinos*. Jaboticabal: Funep. 302p.
- United States (US) Department of Agriculture, Agricultural Research Service. 2018. *USDA National Nutrient Database for Standard Reference Legacy Release April*, 2018. Retrieved Mar 5, 2022, from <https://fdc.nal.usda.gov/fdc-app.html#/food-details/172491/nutrients>
- Zapata, J. F. F., Seabra, L. M. J., Nogueira, C. M., & Barros, N. (2000). Estudo da qualidade da carne ovina do nordeste brasileiro: propriedades físicas e sensoriais. *Food Science and Technology*, 20, 274-277. doi:10.1590/S0101-20612000000200025
- Zeola, N. M. B. L., da Silva Sobrinho, A. G., & Manzi, M. G. (2011). Parâmetros qualitativos da carne de cordeiros submetidos aos modelos de produção orgânico e convencional. *Brazilian Journal of Veterinary Research and Animal Science*, 107-115. Retrieved from <http://hdl.handle.net/11449/72763>