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EFECTO DE LA EDAD DE FAENA DE CORDEROS PESADOS SOBRE LA CALIDAD DE LA CANAL Y LA CARNE

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RESUMEN

Se realizó un estudio para evaluar el efecto de la edad de faena sobre la calidad de la canal y la carne de corderos. Se faenaron 90 corderos criados en sistemas pastoriles durante dos años, correspondientes a tres edades de faena: al destete con 4 meses de edad (4M), a los 6-7 meses de edad (6M) y a los 12 meses de edad (12M), en todos los casos destetados a los 4 meses. El criterio para la faena era lograr pesos de canal caliente de 18-20 kg en promedio en cada tratamiento. Se determinaron el peso de la canal caliente (HCW), el rendimiento de la canal (CYd), el espesor del tejido subcutáneo (GR site), el *frenched rack* (FR), el peso de la pierna y el bife. Después de la maduración, se determinaron el color instrumental, la fuerza de corte (WBSF) y el perfil de ácidos grasos de la grasa intramuscular (IMF) en el músculo *longissimus lumborum,* así como un panel de consumidores. Los corderos de 4M presentaron un mayor HCW, GR y CYd ($P < 0,05$). Los corderos de 12M presentaron mayor proporción de bife y piernas ($P < 0,05$). El FR representó una mayor proporción ($P < 0,05$) de la canal en los corderos 4M y 6M. El color de la carne de los corderos 4M fue más claro (mayores valores de L*) a los 7 y 14 días de maduración y mostró valores más bajos de WBSF a los 14 días de maduración ($P < 0,05$). Se observó mayor proporción de IMF ($P < 0,05$) en los corderos 12M y 4M, pero estos últimos presentaron una mayor relación PUFA/SFA ($P < 0,05$). Los corderos 12M tuvieron una menor proporción de ácidos grasos n6/n3 ($P < 0,05$) y una mayor concentración de α-tocoferol ($P < 0,05$). La carne de los tres grupos de corderos recibió una puntuación positiva (es decir, al menos entre «me gusta mucho» y «me gusta bastante»), en cuanto al gusto general, cuando fue evaluada por consumidores. Aunque se observaron diferencias significativas entre los tres grupos de corderos, la edad de faena de los corderos hasta los 12 meses puede tener un efecto menor sobre la calidad del producto.

Palabras clave: calidad de la canal y carne, corderos, edad

EFFECT OF SLAUGHTER AGE OF HEAVY LAMBS ON CARCASS AND MEAT QUALITY

SUMMARY

A study was conducted to evaluate the effect of age of slaughter on carcass and meat quality of lambs. Ninety lambs reared on pastures were slaughtered for two years corresponding to three ages of slaughter: at weaning with 4 months of age (4M), at 6-7 months of age (6M) and at 12 months of age (12M), weaned at 4 months in every case. The purpose was to achieve hot carcass weights of 18-20 kg on average in each treatment. Hot carcass weight (HCW), carcass yield (CYd), subcutaneous tissue depth (GR site), and *frenched rack* (FR), loin and leg weights were determined. After meat ageing, instrumental color, Warner-Bratzler shear force (WBSF) and fatty acid profile of intramuscular fat (IMF) were determined on *longissimus lumborum* muscle as well as a consumer panel. Lambs of 4M resulted in greater HCW, subcutaneous fat coverage and CYd ($P < 0.05$). Lambs of 12M presented a greater proportion of loins and legs ($P < 0.05$) regarding HCW. *Frenched rack* cut represented a greater proportion ($P < 0.05$) of the carcass in 4M and 6M lambs. Meat color from 4M lambs was lighter (greater L* values) when aged for 7 and 14 days and showed lower WBSF values with 14 days of ageing ($P < 0.05$). A greater proportion of IMF ($P < 0.05$) was observed in 12M and 4M lambs, but the latter presented a greater PUFA/SFA ratio ($P < 0.05$). Older lambs (12M) showed a lower n6/n3 fatty acid ratio ($P < 0.05$) and a greater concentration of α-tocopherol ($P < 0.05$). Meat from the three groups of lambs were scored positively (i.e., at least between “I like moderately” and “I like slightly”) for overall liking when evaluated by consumers. Although significant differences were observed among the three groups of lambs, slaughter age in lambs until 12M seems to have a minor effect on product quality.

Keywords: carcass and meat quality, lamb, age

1. INTRODUCCIÓN

En Uruguay la producción agropecuaria sumada a la industria agroalimentaria representan gran parte de las exportaciones. Siendo la base de la economía en Uruguay durante muchos años, la producción ganadera se ha caracterizado principalmente por los sistemas de producción pastoriles. La producción ovina ha tenido un papel relevante en las exportaciones de Uruguay, representando más del 50 % de estas en algunas décadas de su historia (Ganzábal y Banchero, 2017).

La producción de carne ovina de calidad en Uruguay está asociada a un producto desarrollado en la década del 90: el «cordero pesado». Dicho cordero se originó a partir de cualquiera de los biotipos que se encuentran disponibles en el país, generalmente menor a un año de edad (sin erupción de incisivos permanentes), con un peso de faena entre 34 y 45 kg de peso vivo y con una condición corporal ≥ 3,5 (escala 1 a 5), generando así canales de entre 16 y 20 kg (Azzarini, 2003). Este producto representó una nueva alternativa productiva y de comercialización, complementaria a la producción de lana, destacándose por ser un elemento de diversificación y estímulo de la producción y la rentabilidad de los productores ovinos uruguayos (Montossi et al., 2003). El *stock* ovino del país se encuentra en aproximadamente 6,3 millones de animales (DIEA, 2021). En el año 2019 Uruguay se ubicó como quinto exportador mundial de carne ovina (SUL, 2020), exportando un total de 14.897 toneladas (INAC, 2020).

La mejora de la competitividad de la cadena cárnica ovina debe estar asociada a una mayor productividad y eficiencia del sistema que permita lograr un producto más homogéneo y consistente a lo largo de todo el año. La marcada estacionalidad en la oferta de corderos pesados determina que a nivel nacional no se utilice eficientemente la capacidad industrial instalada y se consolide el abastecimiento regular de los potenciales mercados consumidores (Bianchi, 2001).

Con el objetivo de evaluar la posibilidad de producir corderos todo el año sin comprometer la calidad del producto el presente trabajo evaluó diferentes edades de faena (superprecoz, precoz y tradicional), sobre las características de la canal y carne de corderos pesados.

1.1. CALIDAD DE LA CARNE

La calidad de la carne se define por las cualidades que el consumidor percibe como deseables, que incluyen características visuales y sensoriales y aspectos de credibilidad asociados a la inocuidad y la salud humana. También valora atributos más intangibles, tales como «limpio» y «verde» o aquellos vinculados al bienestar animal del sistema de producción (Becker, 2000). Según Colomer y Rocher (1973), la calidad se define como el «… conjunto de características cuantitativas y cualitativas, cuya importancia relativa confiere a la canal una máxima aceptación y un mayor precio frente a los consumidores o frente a la demanda del mercado».

El color de la carne fresca constituye una característica particularmente relevante que afecta la decisión de compra de los consumidores (Faustman y Cassens, 1990). El color se puede medir instrumentalmente utilizando un colorímetro, por ejemplo, *cone l*, del cual se obtienen los parámetros L* (luminosidad), a* (índice de rojo) y b* (índice de amarillo) del espacio CIELab (CIE, 1986). Algunos autores informaron que el valor de a* aumenta conforme avanza la edad de faena del animal (Dawson et al., 2002, Hopkins et al., 2007), lo cual estaría asociado con un aumento en el contenido de mioglobina (Gardner et al., 2007). El incremento en el contenido de mioglobina conforme avanza la edad del animal refleja el aumento en la capacidad oxidativa del músculo conforme (Greenwood *et al*., 2007). Los consumidores consideran más aceptable el color de la carne de cordero cuando los valores de L* están entre 34 y 35 (Hopkins, 1996) y el valor a* es superior a 9,5 (Khliji et al., 2010). A medida que el animal crece y avanza la edad de faena, el color de la carne sería, promediamente, menos aceptable para los consumidores debido a que se torna más oscura (Hopkins et al., 2005). Por ejemplo, en animales faenados con más de 12 meses de edad puede observarse una disminución en la luminosidad de la carne y en la aceptabilidad del color (Hopkins, 1996). No obstante, Ledward y Shortose (1971) observaron que la edad no era un factor importante para determinar la concentración de mioglobina en el músculo *longissimus dorsi* en corderos cuyas edades de faena variaron entre 98 y 310 días y fueron sacrificados a un peso constante de 32 kg.

Si bien el color de la carne sería la principal característica sobre la que los consumidores basan su decisión de compra, los consumidores australianos de cordero priorizan en primer lugar el sabor y el olor, seguidamente, la terneza y, por último, la jugosidad (Pethick et al., 2006). Esto contrasta con los consumidores de carne vacuna que generalmente consideran la terneza de la carne como el atributo de palatabilidad más importante, influyendo fuertemente en su aceptabilidad por parte de los consumidores (Dikeman, 1987, Miller et al., 1995), aunque esto puede varían según el país (Glitsch, 2000). En algunos estudios no se han observado diferencias entre razas y cruzamientos en la terneza de la carne estimada objetivamente como la fuerza de corte (Dransfield et al., 1979, Hopkins y Fogarty, 1998, Hopkins et al., 2005, Hopkins et al., 2007) o se han hallado diferencias inconsistentes que no fueron explicadas por la variación en otros parámetros que influyen en la terneza, tales como el pH, la longitud del sarcómero, el peso de la canal o los niveles de engrasamiento (Purchas et al., 2002).

Jeremiah et al. (1971) evaluaron instrumentalmente la fuerza de corte (Warner-Bratzler) y sensorialmente, la terneza y jugosidad a través de un panel entrenado, en 5 músculos de la pierna de hembras y machos castrados, cuyas edades estaban comprendidas entre 74 y 665 días. Estos autores observaron correlaciones negativas significativas entre la edad cronológica del animal, la terneza y las pérdidas por cocción de la carne. Las pérdidas por cocción también se correlacionaron negativamente con la terneza evaluada por los panelistas. Por lo tanto, estos investigadores sostienen que el efecto perjudicial del incremento de la edad de la animal sobre la terneza evaluada sensorialmente estaría asociada a un efecto secado de la carne durante su cocción.

1.2. EFECTO DE LA EDAD DE FAENA EN LA CALIDAD DE LA CANAL Y LA CARNE

Ye et al. (2019) estudiaron el impacto de los sistemas comerciales de producción de corderos neozelandeses, que combinan los efectos de la edad de faena y el biotipo animal en la calidad de la canal y la carne. Los corderos eran machos castrados y fueron faenados a los 4 (predestete), 6-8 y 12 meses de edad, logrando pesos de las canales de entre 18,7 y 19,0 kg. Los animales eran de razas compuestas (perendale × texel, finn, romney) en el caso de los corderos faenados a los 4 y 6-8 meses de edad y merino australiano en el caso de los corderos faenados a los 12 meses de edad. La carne de los corderos de 12 meses de edad presentó un mayor pH final y porcentaje de grasa intramuscular que los corderos de 6-8 y 4 meses de edad. Por otra parte, los corderos de menor edad de faena (4 meses) produjeron carne con menores valores de croma (parámetro instrumental del color de la carne que refiere a la intensidad de este), mayores valores de fuerza de corte y mayores proporciones de ácidos grasos poliinsaturados, en comparación con los otros dos grupos de corderos. Los mencionados autores señalaron que, si bien se observaron diferencias significativas en algunas características de calidad de la carne, las diferencias en términos absolutos sugieren que los tres sistemas de producción resultaron en variaciones menores en la calidad de esta.

Hopkins et al. (2005) estudiaron el efecto del biotipo y la edad de faena en la calidad de la carne y reportaron que hubo un efecto menor de la edad de los animales en la aceptabilidad global de la carne valorada por paneles de consumidores. En otro trabajo de los mismos autores, estudiando corderos de cinco genotipos y faenados en cuatro edades diferentes (4, 8, 14 y 22 meses de edad), encontraron que los corderos faenados con 4 meses de edad y al pie de la madre fueron más resistentes al estrés y a la reducción del agotamiento del glicógeno (evaluado por pH en el musculo *semitendinoso*) antes de la faena que corderos desmamados con mayor edad. Estos mismos corderos también presentaron carne una menor fuerza de corte cuando esta fue madurada por 5 días (Hopkins et al., 2007). Los trabajos realizados por Safari et al. (2001) y Dransfield et al. (1979) comparando corderos merino australiano y otros biotipos tales como texel x merino o poll dorset x merino no observaron efecto de la raza del padre en la terneza de la carne evaluada por paneles sensoriales. Sin embargo, Pannier et al. (2014) observaron que la carne de los corderos nacidos de padres de razas terminales fue valorada como menos tierna y tuvo una menor aceptabilidad global por parte del panel de consumidores que aquella proveniente de corderos cuyos padres eran de la raza merino o de una raza materna.

Young et al. (1993) evaluaron a través de un panel de consumidores la carne de corderos de 8 meses de edad engordados sobre pasturas cultivadas y provenientes de 6 cruzamientos con la raza merino. Estos autores no hallaron diferencias entre los 6 biotipos en la jugosidad, el sabor y la aceptabilidad global de la carne, y solo hubo un efecto del biotipo en el caso de la terneza. Hoffman et al. (2003) evaluaron sensorialmente la carne (músculo *semimembranoso*) de 6 biotipos de corderos con 5-6 meses de edad y 40 kg de peso vivo, originados de la cruza de carneros dormer y suffolk y ovejas merino, merino dohne y south african mutton merino. Estos autores no observaron un efecto significativo del biotipo animal en los atributos sensoriales evaluados.

Purchas et al. (2002) evaluaron durante 4 años la calidad de la canal y carne de corderos provenientes de ovejas romney marsh y carneros de otras razas o cruzas, con 2 edades de faena, 5-9 meses y 10-11 meses. Los resultados sugieren que los corderos provenientes de madres romney cruzadas con carneros finn x poll dorset presentaron valores de fuerza de corte ligeramente más altos en el músculo *semimembranoso* en comparación con los corderos romney puros. A su vez, los valores de L* (luminosidad) del color de la carne fueron inferiores en corderos romney puros en uno de los años. No obstante, los autores concluyeron que las diferencias en calidad de la carne debido al efecto del genotipo fueron menores. Sin embargo, observaron que la carne de los corderos faenados a mayor edad era menos tierna que aquella proveniente de los corderos más precoces. Por otra parte, Bonacina et al. (2011) evaluaron tres sistemas de terminación de corderos texel x corriedale: pasturas, pasturas al pie de la madre y pasturas con suplementación (1% PV). La carne de los corderos fue evaluada sensorialmente por 12 jueces seleccionados. Los corderos terminados en pasturas al pie de la madre presentaron una carne con menor intensidad en el olor y el sabor a carne ovina y menor terneza respecto a los otros dos tratamientos. No obstante, Hopkins et al. (2007) reportaron que los corderos en lactación faenados con 4 meses de edad y con un peso de la canal similar al del operativo cordero pesado de nuestro país produjeron la carne con menor fuerza de corte cuando esta fue madurada por 5 días.

1.3. HIPÓTESIS Y OBJETIVOS

1.3.1. Hipótesis

La producción de corderos pesados en Uruguay, cuyo destino es en su gran mayoría la exportación, se caracteriza por una marcada zafralidad en que la faena se concentra en los meses de setiembre a diciembre.

Se plantea como hipótesis que corderos pesados, con un peso de la canal de 18-20 kg, faenados a diferentes edades, no difieren mayormente en la calidad de la carne, más allá de que puedan observarse diferencias a nivel de la canal.

1.3.2. Objetivo general

Evaluar la calidad de la canal y la carne de corderos pesados con diferentes edades de faena (superprecoz, precoz y tradicional), explorando la posibilidad de producir corderos todo el año sin comprometer la calidad del producto.

1.3.3. Objetivos específicos

- Evaluar características asociadas a la calidad de la canal de corderos superprecoces con 4 meses de edad, precoces con 6-7 meses de edad y tradicionales con 10-12 meses de edad;

- Evaluar características asociadas a la calidad de la carne de corderos pesados superprecoces, precoces y tradicionales;

- Conocer la aceptabilidad de la carne proveniente de corderos pesados superprecoces, precoces y tradicionales por parte de los consumidores.

2. EFFECT OF LAMB SLAUGHTER AGE ON CARCASS AND MEAT QUALITY[1]

2.1. ABSTRACT

A study was conducted to evaluate the effect of age of slaughter on carcass and meat quality of lambs. Ninety lambs reared on pastures were slaughtered for two years corresponding to three ages of slaughter: at weaning with 4 months of age (4M), at 6-7 months of age (6M), and at 12 months of age (12M) (last treatments were weaned at 4 months). The purpose was to achieve hot carcass weights of 18-20 kg on average in each treatment. Hot carcass weight (HCW), carcass yield (CYd), subcutaneous tissue depth (GR site), and *frenched rack* (FR), loin and leg weights were determined. After meat ageing, instrumental color, Warner-Bratzler shear force (WBSF) and fatty acid profile of intramuscular fat (IMF) were determined on *longissimus lumborum* muscle as well as a consumer panel. Lambs of 4M resulted in greater HCW, subcutaneous fat coverage and CYd ($P < 0.05$). Lambs of 12M presented a greater proportion of loins and legs ($P < 0.05$) regarding HCW. *Frenched rack* cut represented a greater proportion ($P < 0.05$) of the carcass in 4M and 6M lambs. Meat color from 4M lambs was lighter (greater L* values) when aged for 7 and 14 days and showed lower WBSF values with 14 days of ageing ($P < 0.05$). A greater proportion of IMF ($P < 0.05$) was observed in 12M and 4M lambs, but the latter presented a greater PUFA/SFA ratio ($P < 0.05$). Older lambs (12M) showed a lower n6/n3 fatty acid ratio ($P < 0.05$) and a greater concentration of α-tocopherol ($P < 0.05$). Meat from the three groups of lambs were scored positively (i.e., at least between "I like moderately" and "I like slightly") for overall liking when evaluated by consumers. Although significant differences were observed among the three groups of lambs, slaughter age in lambs until 12M seems to have a minor effect on product quality.

Keywords: Deseasonalize, meat quality, slaughter age

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2.2. INTRODUCTION

Meat quality can be defined as a set of properties appreciated by consumers and mainly associated with our sensory perception such as texture (particularly tenderness), color, flavor, juiciness/water-holding and odor (Purslow, 2017). According to the Sheep Producers Australia (2019), lambs are those animals with less than 12 months of age and without permanent incisors in use. Lamb carcass and meat quality are affected by many factors among which the age at slaughter has been studied (Sañudo et al., 1998). However, it is difficult to recognize if there are true age effects on meat quality traits since animal age is almost invariably confounded with other factors, even though the extent of changes in meat quality as lambs become older is of practical importance as it is required to make some key marketing decisions (Purchas, 2007).

In Uruguay, lambs represented 60 % on average of the total sheep slaughter from 2010 to 2019 (INAC, 2020). These animals are raised mainly on native pastures (Piaggio et al., 2014). Production of lambs based on intensive grazing systems allows to reach slaughter weights earlier than in traditional pastoral systems, but little is known about the magnitude of the effect of age at slaughter on meat quality when maintaining similar slaughter weights. The Uruguayan Heavy Lamb Program accepts animals of any breed, whether male or female, as long as the requirements in terms of slaughter weight (34-45 kg), body condition score (between 3 and 4 in a 5-points scale) and age (milk teeth) are met (Azzarini, 2003). It has been reported that following good animal handling practices and processing conditions, it should be possible to produce lamb meat with satisfactory tenderness with animals up to 20 months of age, although it would depend on the cut (Pethick et al., 2005). In addition, as animal age at slaughter increases, meat color becomes darker (Hopkins et al., 2007a); although, it has also been reported that age is not a major factor in determining myoglobin concentration in lambs from 98 to 310 days old and slaughtered at the same weight (Ledward and Shorthose, 1971).

The hypothesis of the study was that the age of slaughter of lambs up to 12 months old and at similar kill weight has a minor effect on carcass and meat quality attributes. The aim of the present work was to evaluate the effect of age at slaughter on carcass and meat quality traits of lambs reared on grazing systems in order to deseasonalize lamb meat production.

2.3. MATERIALS AND METHODS

2.3.1. Experimental Treatments

For two years, three groups of 30 castrated male and female lambs were slaughtered each year: at weaning with 4 months of age (4M), at 6-7 months of age (6M) and at 12 months of age (12M). Lambs slaughtered at 4M and 6M were a crossbreed texel x corriedale Pro® (25 % east friesian, 25 % finnish landrace and 50 % corriedale) while 12M lambs were from the dual-purpose breed dohne merino. Lambs were slaughtered at 36-40 kg of average live weight to achieve a carcass weight of 18-20 kg. Lambs and their dams during gestation grazed in a pastoral sheep intensive production unit that included pastures such as red clover (*Trifolium pratense*), perennial ryegrass (*Lolium perenne*), *Lotus pedunculatus* and dactylis (*Dactylis glomerata*), with a rotational grazing system of 4-7 days of occupation of the paddocks. The 12M lambs grazed fodder sorghum after their weaning, then they were placed in a natural grassland paddock, and in the final phase of fattening they grazed restrictively (in hourly basis) oats (*Avena sativa L.*) and ryegrass (*Lolium multiflorum*). With the purpose of deseasonalizing lamb production, the experiment aimed to study the effect of slaughter age on carcass and meat quality characteristics rather than genetics and gender. Therefore, these factors were not considered in the present study.

2.3.2. Carcass and Meat Measurements

Lambs were humanely slaughtered in a commercial meat packing plant according to the Uruguayan legislation. Live weight at slaughter (SW), hot carcass weight (HCW) and carcass yield (CYd: (HCW/SW) x 100). After slaughter, carcasses were kept in a cooler for 24 h at 2–4 °C. Subsequently, subcutaneous tissue thickness was determined at the GR point on the 12th rib at 11 cm from the midline of the carcass (Kirton and Johnson, 1979). At the deboning room, right and left *frenched racks*, loins, and legs (boneless, chump-on) were weighed and both *longissimus lumborum* muscles were removed from each carcass which were vacuum packaged and transported to the Meat Laboratory of INIA.

The right *longissimus lumborum* muscle was aged for 7 days and the left was aged for 14 days at 0-2 °C. For both loins, samples were obtained in the cranial-caudal direction for the following determinations: an 8 cm portion for consumer panel and a 5 cm portion for instrumental meat color and Warner-Bratzler shear force. Before meat ageing, a 4 cm portion was removed from the caudal ending of the *longissimus lumborum* muscle for vitamin E content determination (from the right loin) and for fatty acid composition assessment (from the left loin). Both portions were cut into small pieces to be subsequently frozen at -80 ºC and pulverized using a Robot Coupe R2 (Robot Coupe®, Montceau-les-Mines, France). After homogenization, each sample was packed in individual sterile whirl-pack bags (Nasco, Fort Atkinson, WI, USA) and placed into a -80 ºC freezer until analysis were performed. After ageing, instrumental lean color (CIE L*: lightness, a*: redness and b*: yellowness) was measured on each sample in triplicate with a Minolta chromameter CR-400 (Konica Minolta Sensing Inc., Japan) using a C illuminant, a 2° standard observer angle and 8 mm aperture size and calibrated with a white tile before use. Subsequently, meat samples were weighed using an electronic scale (EP-41KA, A&D Company, Tokyo, Japan) before cooking in a preheated clam shell style grill (GRP100 The Next Grilleration, Spectrum Brands, Inc., Miami, FL, USA) until the internal temperature measured with a thermometer (Comark N9094, Norwich, Norfolk, UK) in the geometric center reached 71 °C (AMSA, 2016). After cooking and cooling the pieces, they were weighed again to determine the cooking losses (CL) from the interaction between lamb age at slaughter and ageing period as: [(raw weight – cooked weight)/raw weight] x 100. After this, six cores (1.27 cm diameter) were removed from each meat sample parallel to the longitudinal orientation of muscle fibers and shear force was assessed with a TA.XT Plus texturometer (Stable Micro Systems, Godalming, Surrey, UK) fitted with a Warner Bratzler V-shaped blade (WBSF).

Individual shear force values were averaged to assign a mean peak WBSF value to each sample (AMSA, 2016).

Intramuscular fat (IMF) content was determined gravimetrically as a percentage. The lipid extraction was carried out following the chloroform-methanol method according to the procedure of Bligh and Dyer (1959). Fatty acids were cold methylated with methanolic potash (IUPAC, 1987) and the analysis was carried out by gas chromatography (Konik HRGC 4000B, Barcelona, Spain) using a 30 m DB-WAX capillary column (0.25 mm internal diameter and 0.25 µm film thickness, Agilent, Santa Clara, USA). The carrier gas used was nitrogen with a flow of 1 ml/min. The injection volume was 1 µl and a flame ionization detector (FID) was used. Fatty acids identification was carried out by comparing the retention times with those of a standard (FAME Supelco TM 37, Sigma, St. Louis, USA). Fatty acids were expressed as a percentage of the total fatty acids identified.

Vitamin E (α-tocopherol) content was analyzed following the procedure described by Molino et al. (2012). Briefly, 0.2 g of meat sample were lyophilized (Alpha 1-4LD Plus, Christ, Osterode am Harz, Germany), placed in an eppendorf tube with 0.4 mL of ethyl alcohol and vortexed for 2 minutes. Subsequently, 1 mL of hexane was added and vortexed for 15 minutes and then centrifuged at 3500 rpm for 5 minutes (IEC™ Multi-RF, Themo Scientific, MA, USA). The extraction was performed in triplicate and lipophilic layers were pooled and evaporated under a stream of nitrogen. The dry residue was dissolved in 1 mL of acetonitrile/methanol/dichloromethane (75/15/10) and transferred to a vial from which 80 µL were injected into the HPLC (UltiMate® 3000, Thermo Scientific Dionex, Boston, USA) fitted with a DAD detector. To separate the analyte a C18 chromatographic column of 250 mm x 4.6 mm x 5 µm was used (BDS-Hypersil, Thermo Scientific, Boston, USA). The mobile phase used was a mixture of acetonitrile/methanol/dichloromethane/ammonium acetate 0.05M in water (75/10/10/5) at a flow of 1.5 ml/min with an oven temperature of 35 °C. Quantification of α-tocopherol was performed at 292 nm using a 5-point calibration curve performed with the standard (α-tocopherol, Sigma, St. Louis, USA) and results were expressed as µg/g muscle.

2.3.3. Consumer Panel

On the days of consumer testing, the *longissimus lumborum* portions were thawed the day before and grilled, as previously described, to reach an internal temperature of 71 °C. Consumers evaluated the sensory acceptability of meat aged for 7 and 14 days from the three groups of lambs (six samples in total) following procedures designed to reduce the effects of order of presentation and first order carry-over effects (Macfie et al., 1989*)*. Characteristics of the consumers (gender, age and frequency of meat consumption) that participated in the panel are presented in Table 1.

Each consumer was asked to assess tenderness, flavor and overall liking acceptability on 8-point category scales: like extremely (1), like very much (2), like moderately (3), like slightly (4), dislike slightly (5), dislike moderately (6), dislike very much (7) and dislike extremely (8). Consumers were asked to eat a cracker and rinse their mouths out with water before the evaluation of each sample.

Table 1

Sociodemographic characteristics of consumers.

Variable	Frequency relative (%)
Gender	
Female	37
Male	63
Age	
< 30 years	19
30-50 years	63
> 50 years	18

Table 2

Frequency of consumer´s consumption for pork, beef, chicken, and sheep meat.

Variable	Frequency of consumption (%)			
	Never	Once a month	Every 2 weeks	All weeks
Pork	23	47	20	10
Beef	-	4	8	88
Chicken	1	10	34	55
Sheep	19	44	21	16

2.3.4. Statistical Analysis

The experimental design was completely randomized. The variables were analyzed using a mixed linear model using the MIXED procedure of the Statistical Analysis System (SAS Institute, Cary, NC, version 9.4). The model included the lamb group as a fixed effect, while the animal and the year were considered as random effects. Hot carcass weight (HCW) was adjusted by pre-slaughter live weight (SW), and HCW was used as a covariate for the weight of the valuable cuts. Data from the panel acceptability testing was analyzed as 3 x 2 factorial design where the group of lambs (4M, 6M, and 12M) and ageing times (7 and 14 d) were considered as fixed effect, and consumer, meat sample and year were considered as random effects. Homogeneity of variance and normality for all data were evaluated using studentized residuals plots. Kenward-Roger approximation was used to calculate denominator degrees of freedom for different covariance structures for adjustment of the F-statistic. After ANOVA, least square means were calculated for treatment comparisons with a significance level of $\alpha = 0.05$, using the PDIFF option of LSMEANS adjusted by Tukey, when F-tests were significant ($P < 0.05$).

2.4. RESULTS

2.4.1. Carcass and Meat Quality

Oldest lambs (12M) showed a greater ($P < 0.05$) SW compared to 4M and 6M lambs (Table 3). Lambs slaughtered at 4M of age presented greater ($P < 0.05$) HCW when adjusted by SW than the other two groups of lambs. The tissue depth at the GR point and CYd were adjusted by HCW and 4M lambs had a greater ($P < 0.05$) GR and CYd than 6M and 12M lambs (Table 3).

Leg and loin (adjusted by HCW) presented a greater ($P < 0.05$) proportion of the HCW in 12M lambs compared to 4M and 6M lambs. However, FR presented a greater ($P < 0.05$) proportion of the HCW in 4M and 6M lambs than lambs slaughtered at 12 months of age (Table 3).

Regarding to meat quality traits, no significant differences ($P > 0.05$) were found among the three group of lambs when meat was aged for 7 days. Nevertheless, 4M lambs showed lower ($P < 0.05$) WBSF values than the other two groups of lambs in meat aged for 14 days (Table 3). No significant differences ($P > 0.05$) were found among the three group of lambs for CL of meat aged for 7 and 14 days. Lean color of 4M lambs was li3ghter (greater L* values; $P < 0.05$) than 6M and 12M lambs when meat was aged for 7 and 14 days. In addition, lambs of 6M of age presented greater ($P < 0.05$) L* values than 12M lambs in both ageing times. The a* value (redness) of lean from 12M lambs was greater ($P < 0.05$) than the other two groups and greater ($P < 0.05$) than 6M lambs when meat was aged for 7 and 14 days, respectively (Table 3). Lambs slaughtered at 4M of age showed greater ($P < 0.05$) b* values (yellowness) of meat when aged for 7 days compared to 6M and 12M lambs, and greater ($P < 0.05$) than 12M lambs in meat aged for 14 days.

Table 3

Least square means ± standard error of carcass and meat quality characteristics of lambs slaughtered at 4 months of age (4M), at 6-7 months of age (6M) and at 12 months of age (12M).

	Treatments[1]			
	4M	6M	12M	*P*-value
Carcass traits				
SW[2] (kg)	36.9 ± 0.58[c]	39.9 ± 0.58[b]	43.5 ± 0.59[a]	< 0.0001
HCW[3] (kg)	19.8 ± 0.27[a]	19.3 ± 0.26[b]	18.9 ± 0.27[b]	0.0002
GR[4] (mm)	13.1 ± 1.78[a]	10.7 ± 1.77[b]	6.4 ± 1.78[c]	< 0.0001
CYd[5] (%)	48.7 ± 0.48[a]	47.7 ± 0.48[b]	47.2 ± 0.48[b]	0.0018
Leg (% HCW)	19.2 ± 0.21[b]	18.9 ± 0.21[b]	20.1 ± 0.21[a]	< 0.0001
Frenched rack (% HCW)	5.2 ± 0.11[a]	5.1 ± 0.11[a]	4.8 ± 0.11[b]	< 0.0001
Loin (% HCW)	3.1 ± 0.04[b]	3.0 ± 0.04[b]	3.3 ± 0.04[a]	< 0.0001
Meat quality traits - 7 days ageing				
WBSF[6] (kgf)	2.09 ± 0.11	2.29 ± 0.11	2.14 ± 0.11	0.1221
CL[7] (%)	25.4 ± 1.10	24.3 ± 1.12	23.6 ± 0.93	0.4434
Lightness (L*)	41.0 ± 0.55[a]	38.9 ± 0.55[b]	34.4 ± 0.55[c]	< 0.0001
Redness (a*)	19.5 ± 0.37[b]	19.4 ± 0.37[b]	20.1 ± 0.36[a]	0.0048
Yellowness (b*)	8.8 ± 0.15[a]	8.0 ± 0.15[b]	7.7 ± 0.15[b]	< 0.0001
Meat quality traits - 14 days ageing				
WBSF[6] (kgf)	1.58 ± 0.09[a]	2.02 ± 0.09[c]	1.76 ± 0.09[b]	< 0.0001
CL[7] (%)	24.4 ± 1.01	25.7 ± 1.11	23.9 ± 1.30	0.4434
Lightness (L*)	41.0 ± 0.49[a]	39.3 ± 0.49[b]	35.2 ± 0.49[c]	< 0.0001
Redness (a*)	19.6 ± 0.66[a]	19.0 ± 0.66[b]	19.7 ± 0.66[a]	0.0026
Yellowness (b*)	8.9 ± 0.31[a]	8.6 ± 0.31[a]	7.3 ± 0.31[b]	< 0.0001

[a, b, c] LS Means with different superscripts in the same row differ significantly ($P < 0.05$). [1] 4M: lambs with 4 months of age; 6M: lambs with 6-7 months of age; 12M: lambs with 12 months of age. [2] SW: slaughter weight. [3] HCW: hot carcass weight adjusted by SW. [4] GR: total tissue depth over the 12th rib at 11 cm from the midline of the carcass, adjusted by HCW. [5] CYd: carcass yield = (HCW/SW) x 100. [6]WBSF: Warner-Bratzler shear force. [7] CL: Cooking loss.

Lambs slaughtered at 4M and 12M of age showed greater ($P < 0.05$) IMF content than 6M lambs (Table 4). In our study, the younger lambs (4M) presented a greater ($P < 0.05$) concentration of conjugated linoleic acid (CLA) compared to the other two groups. No significant differences ($P > 0.05$) were observed among the three groups of lambs on proportion of saturated fatty acids (SFA). The oldest lambs (12M) presented a greater ($P < 0.05$) proportion of monounsaturated fatty acids (MUFA) compared to 4M and 6M lambs. Younger lambs (4M) showed a greater ($P < 0.05$) proportion of polyunsaturated fatty acids (PUFA) and polyunsaturated fatty acids/saturated fatty acids ratio (PUFA/SFA) than the other two groups of lambs (Table 4). Regarding the proportion of omega 6/omega 3 fatty acids (n6/n3), meat from 4M and 6M lambs showed a greater ($P < 0.05$) ratio than 12M lambs. The oldest lambs (12M) presented the greatest ($P < 0.05$) concentration of vitamin E (α-tocoferol) on the *longissimus lumborum* muscle, while 4M lambs showed the lowest ($P < 0.05$) concentration (Table 4).

Table 4

Least square means ± standard error of intramuscular fat content, fatty acids composition (% of the total fatty acids identified) and α-tocopherol concentration of the *longissimus lumborum* muscle of lambs slaughtered at 4 months of age (4M), at 6-7 months of age (6M) and at 12 months of age (12M).

Variable	Treatments[1]			
	4M	6M	12M	*P*-value
Intramuscular fat IMF (%)	4.92 ± 0.69[a]	4.21 ± 0.69[b]	4.98 ± 0.70[a]	0.0011
Fatty acids (%)				
C14:0 (*myristic*)	5.18 ± 0.25[a]	3.13 ± 0.25[b]	1.98 ± 0.25[c]	< 0.0001
C16:0 (*palmitic*)	28.6 ± 1.50[a]	27.2 ± 1.50[b]	24.4 ± 1.50[c]	< 0.0001
C18:0 (*stearic*)	14.5 ± 0.93[c]	18.1 ± 0.93[b]	21.6 ± 0.93[a]	< 0.0001
C20:0 (*arachidic*)	0.37 ± 0.05[a]	0.31 ± 0.05[b]	0.35 ± 0.05[a]	< 0.0001
C14:1 (*myristoleic*)	0.20 ± 0.11[c]	0.26 ± 0.11[b]	0.32 ± 0.11[a]	< 0.0001
C16:1 (*palmitoleic*)	1.79 ± 0.04[a]	1.32 ± 0.04[b]	1.24 ± 0.04[b]	< 0.0001
C18:1-n9 (*oleic*)	37.8 ± 0.33[b]	38.4 ± 0.33[b]	42.2 ± 0.33[a]	< 0.0001
C18:2-n6 (*linoleic*)	3.89 ± 0.24[a]	3.77 ± 0.24[a]	2.71 ± 0.24[b]	< 0.0001
CLA (*conjugated linoleic*)	1.56 ± 0.15[a]	1.13 ± 0.15[b]	1.06 ± 0.15[b]	< 0.0001
C18:3-n3 (*linolenic*)	2.18 ± 0.11[a]	1.86 ± 0.11[b]	1.40 ± 0.11[c]	< 0.0001
C18:3-n6 (*linolenic*)	0.09 ± 0.008[b]	0.09 ± 0.008[b]	0.13 ± 0.008[a]	< 0.0001
C20:2-n6 (*eicosadienoic*)	0.07 ± 0.032[c]	0.11 ± 0.033[b]	0.13 ± 0.032[a]	< 0.0001
C20:3-n3 (*eicosatrienoic*)	0.21 ± 0.041[b]	0.28 ± 0.041[a]	0.19 ± 0.041[b]	< 0.0001
C20:3-n6 (*DGLA*)	0.21 ± 0.021[b]	0.23 ± 0.021[ab]	0.26 ± 0.032[a]	< 0.0001
C20:4-n6 (*arachidonic*)	1.20 ± 0.08[a]	1.27 ± 0.07[a]	0.78 ± 0.07[b]	< 0.0001
C20:5-n3 (*EPA*)	0.74 ± 0.056[a]	0.68 ± 0.056[ab]	0.62 ± 0.056[b]	0.0481
C22:5-n3 (*DPA*)	0.55 ± 0.030[a]	0.59 ± 0.030[a]	0.49 ± 0.030[b]	0.0007
C22:6-n3 (*DHA*)	0.14 ± 0.016[a]	0.13 ± 0.016[ab]	0.12 ± 0.016[b]	0.0094
SFA[2] (%)	48.7 ± 0.85	48.7 ± 0.85	48.3 ± 0.85	0.4181
MUFA[3] (%)	39.8 ± 0.39[b]	40.0 ± 0.39[b]	43.8 ± 0.39[a]	< 0.0001
PUFA[4] (%)	11.5 ± 0.28[a]	10.4 ± 0.29[b]	7.8 ± 0.28[c]	< 0.0001
PUFA/SFA ratio	0.24 ± 0.009[a]	0.21 ± 0.009[b]	0.16 ± 0.009[c]	< 0.0001
n6/n3[5] ratio	1.88 ± 0.20[a]	1.91 ± 0.20[a]	1.69 ± 0.20[b]	0.0002
α-tocoferol (µg/g muscle)	1.443 ± 0.571[c]	1.826 ± 0.571[b]	3.125 ± 0.571[a]	< 0.0001

[a, b, c] LS Means with different superscripts in the same row differ significantly ($P < 0.05$). [1] 4M: lambs with 4 months of age; 6M: lambs with 6-7 months of age; 12M: lambs with 12 months of age. [2] SFA:

saturated fatty acids, ∑ C14:0 + C16:0 + C18:0 + C20:0. [3] MUFA: monounsaturated fatty acids, ∑ C14:1 + C16:1 + C18:1n9. [4] PUFA: polyunsaturated fatty acids, ∑ C18:2n6 + C18:3n6 + C18:3n3 + CLA + C20:2n6 + C20:3n3 + C20:3n6 + C20:4n6 + C20:5n3 + C22:5n3 + C22:6n3. [5] n-6: omega 6 fatty acids, ∑ C18:2n6 + C18:3n6 + C20:2n6 + C20:3n6 + C20:4n6. n-3: omega 3 fatty acids, ∑ C18:3n3 + C20:3n3 + C20:5n3 + C22:5n3 + C22:6n3.

2.4.2. Consumers Panel

Meat from 4M lambs was scored higher (P < 0.05) for tenderness than 6M and 12M lambs, although tenderness mean score of the three groups of lambs were between "I like moderately":3 to "I like slightly":4 (Table 5). Meat flavor acceptability and overall liking was greater (P < 0.05) for 4M lambs than 12M lambs while 6M lambs did not differ (P > 0.05) from these two groups (Table 5). It is important to note that the three groups of lambs were scored positively (i.e.: at least as "I like slightly") for the three attributes. Meat ageing time (7 vs. 14 days) did not show an effect (P > 0.05) on any attribute evaluated by consumers and no interaction (P > 0.05) was observed between lamb age at slaughter and ageing period (data not presented).

Table 5

Least square means ± standard error for tenderness, flavor and overall liking scores of meat from lambs slaughtered at 4 months of age (4M), at 6-7 months of age (6M) and at 12 months of age (12M) averaged over ageing time (7 and 14 days) evaluated by a consumers panel (n = 200).

Variable	Treatments[1]			
	4M	6M	12M	*P*-value
Tenderness[2]	2.11 ± 0.15^{a}	2.51 ± 0.15^{b}	2.66 ± 0.15^{b}	< 0.0001
Flavor[2]	2.94 ± 0.17^{a}	3.08 ± 0.18^{ab}	3.19 ± 0.18^{b}	0.0388
Overall liking [2]	2.84 ± 0.08^{a}	3.03 ± 0.08^{ab}	3.23 ± 0.08^{b}	0.0005

[a, b, c] Means within a row with different superscripts differ (P < 0.05). [1] 4M: at weaning with 4 months of age, 6M: at 6-7 months of age, 12M: at 12 months of age. [2]: 8-point category scales: like extremely (1), like very much (2), like moderately (3), like slightly (4), dislike slightly (5), dislike moderately (6), dislike very much (7) and dislike extremely (8).

2.5. DISCUSSION

Hot carcass weight and degree of fatness are important characteristics associated to the value of the lamb (De Brito et al., 2016). In our study, 4M lambs showed a greater HCW (adjusted by SW) than the other two groups, which agrees with previous studies where 4-month-old lambs presented heavier HCW than older lambs (Kim et al., 2012; Ye et al., 2020a). The tissue depth at the GR point was also greater in 4M lambs, probably associated to animal biotype effect (Ye et al., 2019), but also could be due to a higher energy concentration during breastfeeding. It has been stated that lambs slaughtered at weaning probably had a higher growth rate because of milk intake prior to slaughter, which would result in greater muscle development and fat deposition (Ye et al., 2020a). In addition, the greater CYd of 4M lambs could be explained by the gastrointestinal tract, including the rumen, that would not yet be fully developed (Hatfield, 1994). Cifuni et al. (2000) reported that CYd decreases as the slaughter age of young lambs increases. With increasing carcass weight, greater muscle proportions can be achieved and consequently an increase in the weight of valuable cuts (Cruickshank et al., 1996; Parilo et al., 2007). While valuable cuts were adjusted by HCW, 12M lambs presented a greater proportion of legs and loins and lower proportion of FR regarding the HCW than 4M and 6M lambs. Borton et al. (2005) did not find significant differences in the proportion of FR and loins regarding HCW in heavy lambs at two slaughter end weights, 52 and 77 kg. Cañeque et al. (1999) reported that in light lambs slaughtered at three live weights (10, 12 and 14 kg) the leg cuts represented approximately 33 % of the carcass weight, but in our study, legs represented between 18 and 20 % of the HCW since our lambs were heavier.

Tenderness is one of the most important attributes of meat quality, being affected by animal age (Maltin et al., 2003), breed, alterations in the myofibrillar structure, content and solubility of the connective tissue and the type of muscle (Fayemi and Muchenje, 2019; Harris, 1976; Obuz and Dikeman, 2003; Silva et al., 1993). In the present study, WBSF was evaluated with two ageing times. No differences on WBSF were detected among the three groups of lambs when meat was aged for 7 days. Even though Starkey et al. (2015) suggest that ageing lamb meat for more than 7 days would not improve the shear force of *longissimus* muscle, we considered interesting to evaluate if there would be a differential effect of slaughter age on WBSF and thus it was also aged for 14 days. Meat of the 4M lambs aged for 14 days had lower WBSF than older lambs, although shear force values were in all cases below 2.5 kgf, which would indicate very tender meats (Shorthose et al., 1986). This was confirmed in some extent by consumers since tenderness mean scores of the three groups of lambs were between "I like very much" to "I like moderately". Safari et al. (2001) found that a WBSF value range between 3 and 4 kgf would be needed to achieve a tenderness score above 50 on a 100-point scale in lamb loins evaluated by trained panelists. More recent research conducted by Hopkins et al. (2006) suggested that loins must have a shear force value of about 27 N (2.75 kgf) or less to achieve the mean overall liking score of 63 on a 100-point scale.

Meat color is the main characteristic on which consumers base their purchase decision (Faustman and Cassens, 1990; Mancini and Hunt, 2005). Meat cuts that do not have a good appearance and color are poorly accepted by consumers and end up losing their commercial value (Li and Liu, 2012). Meat color of 4M lambs was lighter (greater L* values) than 6M and 12M lambs. These results agree with the findings of Hopkins et al. (2007b), where greater L* values were observed on lambs slaughtered at 4 months of age compared to those slaughtered at 22 months. Lean color of the loins aged for 7 days from the 12M lambs presented greater values of a* (redness), which could be attributed to a greater myoglobin content that occurs as age increases, influencing a greater oxidative capacity (Gardner et al., 2007; Hopkins et al., 2007b; Warner et al., 2007). Khliji et al. (2010) reported that if the L* and a* values are equal or above 34 and 9.5, respectively, on average, consumers will consider the meat color acceptable in Australia. Our results showed values of L* (lightness) and a* (redness) close or above that benchmark. In the present study, the b* values were greater on meat of 4M lambs aged for 7 days, while for 14 days of ageing, the 4M and 6M lambs presented greater values. We expected greater b* values on meat of the oldest lambs (12M) since grass-fed animals present higher concentrations of carotenoid pigments in intramuscular fat (Scollan et al., 2006), but probably the myoglobin redox state play also an important role affecting the b* coordinate of meat color (Mancini and Hunt, 2005).

Intramuscular fat contributes to the nutritional value, palatability and consumer's acceptability, influencing meat juiciness, flavor and tenderness (Fowler et al., 2020; Shorthose and Harris, 1991; Thompson, 2004). Meat of 4M and 12M lambs presented the greatest levels of IMF. Nevertheless, it was observed that lambs slaughtered at 4 and 6-8 months of age did not differ between them (IMF: 2.92 and 2.89 %, respectively) and had lower intramuscular fat content than those slaughtered at 12 months (3.52 %) fed on mixed pasture (Ye et al., 2019), and similar results were also reported by Mashele et al. (2017). Intramuscular fat content in all three groups of lambs were in the range of 4.21-4.98 %. Hopkins et al. (2006) reported that it was required an intramuscular fat content close to 5 % to achieve the mean overall liking score when meat was tasted by consumers. However, these authors indicated that intramuscular fat explained only 3 % of the variation in overall liking.

Fatty acid composition is relevant for consumers in terms of the nutritional value and its impact on human health, but it also influences meat characteristics such as flavor and shelf life (Wood et al., 2003). In our study, no significant differences were found among the groups of lambs in the proportion of SFA. The omega 6/omega 3 ratio in the three groups of lambs was below the maximum value of 4, recommended by the Department of Health (1994) of the United Kingdom. This department (1994) also recommended a PUFA/SFA ratio greater than 0.45, although this value was not achieved by any group of lambs since PUFAs are biohydrogenated in the rumen by the action of bacteria, which determines a low PUFA/SFA ratio (Banskalieva et al., 2000; Harfoot and Hazlewood, 1988). However, the 4M lambs presented a greater ratio, most likely because of lower biohydrogenation. Intramuscular fat of 12M lambs presented a greater MUFA proportion compared to the other two groups of lambs, while 4M lambs presented a greater percentage of PUFA than the other treatments. Díaz et al. (2005) observed, a greater proportion of MUFA (42.6 %) in the IMF of the *longissimus dorsi* muscle in Uruguayan heavy lambs slaughtered at 12-13 months of age compared with Uruguayan light lambs (37.9 %) slaughtered at 3-4 months. Agreeing with our results, Ye et al. (2020b) found a greater proportion of MUFA in merino lambs slaughtered at 12 months of age than those of the composite breed slaughtered at 4 months of age, and a lower proportion of PUFA in merino lambs compared to lambs slaughtered at 4 and 6-8 months of age. According to Ogawa et al. (2001), conjugated linoleic acid (CLA) has attracted much attention in the last decades due to its beneficial effects on health although scientific evidence is controversial about such effects (Benjamin et al., 2015). CLA is an intermediate compound in the ruminal biohydrogenation process of C18:2n-6 to its conversion to C18:0 (Griinari and Bauman, 1999). In our study, lambs slaughtered with 4M presented a greater proportion of CLA than 6M and 12M lambs. These results agree with the findings of Ye et al. (2020b), in which lambs slaughtered at 4 months of age presented a greater proportion of CLA than 6-8 months old lambs grazing perennial ryegrass-based pasture. The greater CLA proportion of 4M lambs could be attributed to the milk ingested by them from pasture-fed ewes (Gonzales-Barron et al., 2021).

Antioxidants such as α-tocopherol are essential in muscle tissue to protect both lipid and myoglobin from oxidation, contributing to extend meat shelf life (Arnold et al., 1993; Faustman et al., 1998). Previous studies have reported concentrations of α-tocopherol necessary to delay oxidative processes and deterioration of lamb meat color, which range from 3.1 to 4.0 mg/kg of muscle (Jose et al., 2016; Ponnampalam et al., 2021; Ponnampalam et al., 2012). In our study, 12M lambs presented the greatest concentration of α-tocopherol in muscle since those lambs grazed for longer time. Green pastures have high concentrations of α-tocopherol (Li y Liu, 2012) that resulted in concentrations above 3 µg/g of muscle. However, 6M lambs presented a lower α-tocopherol content of 1.8 µg/g of muscle, which agrees with that reported by Petron et al. (2007) in lambs that grazed ryegrass and were slaughtered with the same age. As it was expected, the lowest concentration of α-tocopherol was observed in 4M lambs that were slaughtered after weaning and had a smaller contribution of the pastures in their diets, which could impact negatively in the meat retail shelf life.

Consumer’s acceptability of meat is affected by cultural aspects, consumption habits, and previous experiences and besides preferences of sensory attributes are not homogenous among consumers (Font-i-Furnols and Guerrero, 2014). It has been stated that evaluations with consumers are important to understand how their preferences are generated (Chong et al., 2020; Font-i-Furnols et al., 2009; Realini et al., 2009). Tenderness, juiciness and flavor represent the main characteristics of meat palatability that are linked to consumer satisfaction (Garmyn, 2020; Maltin et al., 2003). In this experiment, tenderness, flavor and overall liking of meat from 4M lambs were preferred by consumers rather than meat from 12M lambs. Meat of the 6M lambs did not differ from either of the other two groups of lambs in the score of its flavor and overall liking. It is important to note that the three groups of lambs were rated with positive scores, i.e., at least between “like slightly” and "like moderately". Previous research has shown that legs from 15-month-old sheep was as acceptable as that from 5-month-old lambs by consumer taste panel in terms of tenderness, flavor and juiciness (Kirton et al., 1974). Wiese et al. (2005) found no difference in the scores for overall liking assessed by consumers among meat aged for 4 days from lambs with milk teeth, partial eruption of permanent teeth, or both permanent teeth fully erupted. However, these authors also observed that the oldest lambs were scored higher for tenderness and juiciness than the youngest ones. Furthermore, Pethick et al. (2005) found no differences in the consumer overall liking scores between 8.5- month-old lamb and 20-month-old sheep for the *biceps femoris* and *longissimus lumborum* muscles. These authors pointed out that when sheep meat is denuded of subcutaneous and intermuscular fat, the flavor becomes less evident and thus the age effect is less relevant. Payne et al. (2020) did not observe differences in consumer eating quality scores between lambs of 240 vs. 328 days of age for the loin, leg, shoulder and rack.

In addition, results from our experiment showed no differences on tenderness, flavor and overall liking scores as consequence of the ageing period (7 vs. 14 days). These results indicated that extending the ageing period for more than 7 days did not improve the eating quality of lamb meat even though 4M lambs showed lower WBSF values than the other two groups of lambs in meat aged for 14 days.

2.6. CONCLUSIONS

Results from the present study showed that 4M lambs produced heavier carcasses, with greater fat thickness and carcass yield. Regarding meat quality, WBSF values of the three groups of lambs (4M, 6M and 12M) would allow to assert that tender or very tender meats were produced in all cases, which was positively evaluated by the consumer panel. Youngest lambs (4M) presented lighter meat (greater L* values), being more attractive to the consumers. A greater PUFA/SFA ratio of intramuscular fat and a lower concentration of vitamin E would determine that 4M lambs meat would be more susceptible to oxidation.

Meat from the three types of lambs were scored positively (i.e., at least between "I like moderately" and "I like slightly") for overall liking when evaluated by consumers. Although differences were observed among the three groups of lambs, slaughter age in lambs until 12M seems to have a minor effect on product quality.

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Declaration of Competing Interest

The authors declare no conflict of interest.

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3. RESULTADOS Y DISCUSIÓN GENERALES

Abdullah y Qudsieh (2008) y Santos-Silva y Portugal (2001) consideran que faenar corderos con pesos vivos preembarque mayores a 35 kg permite aumentar el grado de cobertura de grasa de la canal sin perjudicar su calidad. El peso de la canal caliente del presente trabajo fue mayor en los corderos 12M ($P < 0,05$) en comparación con los otros dos tratamientos (Tabla 6). Cuando el peso de la canal caliente fue ajustado por el peso vivo prefaena, los corderos 4M presentaron canales significativamente más pesadas ($P < 0,05$) con relación a los corderos 6M y 12M, no difiriendo ($P > 0,05$) estos últimos entre ellos. En nuestro trabajo, todos los pesos de las canales registradas estuvieron entre 18 y 21 kg, siendo este rango de peso el preferido por la industria dentro del Operativo Cordero Pesado. De acuerdo con lo reportado por Montossi (2002), en países como Australia y Nueva Zelanda, los factores que determinan el precio final y la comercialización son el peso y el grado de cobertura de grasa de la canal.

Según Ponnampalam et al. (2008), la grasa es un tejido que se deposita más tardíamente en el desarrollo del animal, por lo que sería de esperar un menor espesor de grasa subcutánea en los animales faenados a menor edad que aquellos sacrificados con una edad más avanzada (Mashele et al., 2017, Pannier et al., 2014). Sin embargo, en nuestro trabajo en la variable GR sin y con ajuste, los corderos 4M tuvieron los mayores valores ($P < 0,05$) en comparación a los otros dos tipos de corderos. En relación al rendimiento de la canal, los corderos 4M presentaron mayores ($P < 0,05$) pesos en comparación con los corderos 6M y 12M ($P > 0,05$), que, a su vez, no difirieron entre ellos (Tabla 6).

En cuanto a los cortes valiosos, la pierna fue más pesada y representó una mayor proporción de la canal ($P < 0,05$) en los corderos 12M, mientras que no hubo diferencias significativas ($P > 0,05$) entre los corderos 4M y 6M. El peso y la proporción del *frenched rack* en la canal de los corderos 4M y 6M fueron mayores ($P < 0,05$) que en los corderos 12M. El peso del bife de los corderos 12M y 4M no difirió entre ellos ($P > 0,05$), pero fue más pesado ($P < 0,05$) que el de los corderos 6M. Por otra parte, la proporción del bife respecto a la canal fue mayor ($P < 0,05$) en el cordero

12M en comparación con los corderos 4M y 6M, los cuales no difirieron entre ellos (P > 0,05). Cañeque et al. (1999) reportaron que en corderos livianos los cortes de la pierna con hueso representaban aproximadamente un 33 % de la canal. En nuestro estudio, los rendimientos de la PSH representaron entre el 18 y el 20 % de la canal.

Las mediciones de tipificación de la canal se encuentran en la Tabla 7. Los corderos 4M presentaron una conformación superior (S) en el 43 % de sus canales, mientras que dicha proporción fue de 38 % y 35 % para los corderos 6M y 12M, respectivamente. No se observaron canales con conformación insuficiente (I) en ninguno de los tres grupos de corderos y la conformación media (M) solo se registró en el 1,7 % de las canales de los corderos 6M. El 85 % de las canales de los corderos 12M presentaron una terminación moderada, mientras que el 63 % y el 35 % de las canales de los corderos 4M y 6M, respectivamente, presentaron coberturas de grasa abundante y excesiva. El 82 % de las canales de los corderos 12M presentaron un rango de espesor de tejido subcutáneo (GR) de entre 6 y 12 mm, el cual estaría asociado a un nivel moderado de cobertura de grasa. Los corderos 4M presentaron espesores del tejido subcutáneo mayores a 12 mm en el 61 % de sus canales, lo cual podría estar indicando excesiva cobertura de grasa.

Tabla 6. Media de los mínimos cuadrados ± error estándar de las características asociadas a la canal.

Valores	Tratamientos[1]			
	4M	6M	12M	*P*
Peso de canal caliente (kg)	18,0 ± 0,25[c]	19,0 ± 0,25[b]	20,9 ± 0,26[a]	< 0,0001
Peso de canal caliente[2] (kg)	19,8 ± 0,27[a]	19,3 ± 0,26[b]	18,9 ± 0,27[b]	0,0002
GR[3] (mm)	12,4 ± 1,88[a]	10,6 ± 1,88[b]	7,1 ± 1,88[c]	< 0,0001
GR[3,4] (mm)	13,1 ± 1,78[a]	10,7 ± 1,77[b]	6,4 ± 1,78[c]	< 0,0001
Rendimiento (%)	48,7 ± 0,48[a]	47,7 ± 0,48[b]	47,2 ± 0,48[b]	0,0018
Pierna[4] (kg)	1,850 ± 0,019[b]	1,829 ± 0,019[b]	1,945 ± 0,019[a]	< 0,0001
Pierna[4] (%HCW)	19,2 ± 0,21[b]	18,9 ± 0,21[b]	20,1 ± 0,21[a]	< 0,0001
Frenched rack[4] (kg)	0,501 ± 0,011[a]	0,490 ± 0,011[a]	0,462 ± 0,011[b]	< 0,0001
Frenched rack[4] (% HCW)	5,2 ± 0,11[a]	5,1 ± 0,11[a]	4,8 ± 0,11[b]	< 0,0001
Bife[4] (kg)	0,303 ± 0,004[a]	0,290 ± 0,004[b]	0,321 ± 0,004[a]	< 0,0001
Bife[4] (% HCW)	3,1 ± 0,04[b]	3,0 ± 0,04[b]	3,3 ± 0,04[a]	< 0,0001

Nota: Diferentes letras dentro de la línea indican diferencias significativas ($P < 0,05$). [1] 4M: superprecoz, 6M: precoz, 12M: tradicional. [2] Peso ajustado por el peso vivo final. [3] Espesor de tejido subcutáneo medido en el punto GR, sobre la 12.ª costilla a 11 cm de la línea media de la canal. [4] Peso ajustado por el peso de la canal caliente (HCW).

Tabla 7. Distribución de las canales según su tipificación (tipo de conformación y grado de terminación) y espesor del tejido subcutáneo medido en el punto GR.

Valores	Tratamientos[1]		
	4M	6M	12M
Conformación[2] (%)			
S	43,3	38,3	35,0
P	56,7	60,0	65,0
M	-	1,7	-
I	-	-	-
Terminación[3] (%)			
1	5,0	10,0	11,7
2	31,7	55,0	85,0
3	46,7	13,3	3,3
4	16,7	21,7	-
GR[4] (%)			
< 6 mm	2	4	18
6 - 12 mm	37	51	82
> 12 mm	61	45	-

[1] 4M: superprecoz, 6M: precoz, 12M: tradicional. [2] S = superior, P = primera, M = media. [3] 1 = escasa, 2 = moderada, 3 = abundante, 4 = excesiva. [4] Espesor de tejido subcutáneo medido en el punto GR, sobre la 12.ª costilla a 11 cm de la línea media de la canal.

4. CONCLUSIONES

Los resultados obtenidos en este trabajo muestran que faenar los corderos superprecoces de 4 meses de edad que califican para el Operativo Cordero Pesado permitiría obtener canales más pesadas y mayor nivel de cobertura de grasa (medido en el punto GR), así como un mayor rendimiento de la canal.

Los valores de fuerza de la carne indicaron que los tres tipos de corderos pesados produjeron carnes tiernas o muy tiernas, lo cual fue positivamente valorado por el panel de consumidores. Por otra parte, los corderos superprecoces (4M) presentaron carne más luminosa (L*), con una mayor relación PUFA/SFA en la grasa intramuscular y una menor concentración de vitamina E. Es importante destacar que, desde el punto de vista sensorial, la carne de los tres tipos de corderos fue valorada positivamente (al menos «me gusta») respecto a su aceptabilidad global por parte de los consumidores.

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