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S.C.A. Los Filabres

ESTUDIO DE LAS CARACTERÍSTICAS DE LA CANAL Y DE LA CARNE EN CABRITOS DE RAZA ‘MURCIANO–GRANADINA’

Memoria presentada por Pedro Zurita Herrera para optar al título de Doctor

TITULO: *CARACTERÍSTICAS DE LA CANAL Y DE LA CARNE EN CABRITOS DE RAZA &quot"MURCIANO-GRANADINA&quot"*

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Córdoba, 2013

TÍTULO DE LA TESIS: ESTUDIO DE LAS CARACTERÍSTICAS DE LA CANAL Y DE LA CARNE EN CABRITOS DE ‘RAZA MURCIANO–GRANADINA’

DOCTORANDO: PEDRO ZURITA HERRERA

INFORME RAZONADO DE LOS DIRECTORES DE LA TESIS

La evolución y desarrollo de la tesis doctoral ha cumplido sobradamente con los objetivos inicialmente propuestos, cumpliendo así las expectativas que desde un principio fueron depositadas en el doctorando y en su labor investigadora. Muestra de esta positiva evolución y del acertado desarrollo de la tesis son una serie de publicaciones, tres de las cuales componen la presente tesis. Además de esas tres publicaciones, caben destacar las siguientes: “Organic vs conventional herd effects on the weights and daily gains in Murciano–Granadina kids” (Tropical and Subtropical Agroecosystems, 11, 98–99); “La calidad de la canal en cabritos de raza Murciano–Granadina” (FEAGAS, 35, 113-117).
Además, a lo largo del desarrollo de la tesis doctoral, y fruto de dicho desarrollo, también fueron una serie de comunicaciones a conferencias y simposios, entre los cuales destacan los siguientes: X Simposio Iberoamericano sobre Conservación y Utilización de Recursos Zoogenéticos, en Palmira (Colombia), del 1 al 13 de noviembre de 2009; 9th Internacional Conference on Gotas, en Méjico, del 31 de agosto al 5 de septiembre de 2008); IX Simposio iberoamericano sobre conservación y utilización de recursos zoogenéticos (IX Latin American Symposium on Conservation and Utilization of Animal Genetic Resources), en Mar de la Plata, Buenos Aires, Argentina, del 10 al 12 de diciembre de 2008).

En definitiva, los directores de la tesis así como el tutor del doctorando, constatan que esta memoria titulada “Estudio de las características de la canal y de la carne en cabritos de raza Murciano–Granadina”, presentada por Don Pedro Zurita Herrera, reúne todos lo requisitos que permiten su presentación y defensa para optar al grado de Doctor.

Por todo ello, se autoriza la presentación de la tesis doctoral.

Córdoba, ____ de _________________ de ____________

Firma de los directores | Firma del tutor

Fdo.: María Esperanza Camacho Vallejo

Fdo.: Anastasio Argüello Henríquez

Fdo.: Juan Vicente Delgado Bermejo

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RESUMEN.— El objetivo de este estudio fue contribuir a la caracterización de la producción cárnica de la raza caprina Murciano–Granadina. Para ello se analizó el efecto de tres sistemas de explotación en el crecimiento, calidad de la canal y calidad de la carne de 61 cabritos de la raza, así como su interacción con el sexo. Los cabritos del sistema intensivo con lactancia natural (en adelante, SILN) y del sistema extensivo (en adelante, SE), crecieron más rápido que los animales del sistema intensivo con lactancia artificial (en adelante, SILA). Los cabritos del SILA tuvieron los menores porcentajes de rendimiento real a la canal debido al mayor desarrollo de su tracto gastrointestinal. La pierna y la canal fueron de mayor longitud en los cabritos del SE. Las canales y los cortes del SILN y del SE contenían más grasa que en los cabritos procedentes del SILA. Los machos crecieron más rápido que las hembras. Las canales de los machos tuvieron un mayor contenido en hueso pero menor en grasa que las canales de las hembras. Los cabritos del SE mostraron carnes más rosas que los del SILN y del SILA. La carne procedente de cabritos del SILA mostró la menor capacidad de retención de agua. Los depósitos de grasa intramuscular de cabritos criados bajo el SE poseyeron el porcentaje más bajo de ácido mirístico (C14:0) y el más alto de C18:1 (ácido oleico). El SE produce carne de cabritos parecida a la del SILN y a la del SILA, pero con un menor índice de aterogenicidad. Los datos de crecimiento, calidad de la canal y calidad de la carne se recogieron y se llevó a cabo el análisis discriminante canónico y el análisis de conglomerados sobre el proceso completo de producción de la carne así como de sus diferentes fases, empleándose los sistemas de explotación como criterio de agrupamiento. Todas las comparaciones mostraron diferencias significativas e indicaron la existencia de tres productos con diferentes características de calidad como resultado de la influencia del sistema de explotación. Así mismo, el análisis de correlaciones canónicas realizado entre grupos de variables de crecimiento, de características de la carne y de características de la canal, mostraron importantes relaciones entre las fases de producción, de procesado y de comercialización.

ABSTRACT.— The aim of this research was to contribute to the characterization of meat production of Murciano–Granadina goat breed. To achieve this goal we analyzed the effect of three management systems on growth, carcass quality and meat quality of 61 breed kids and their interaction with sex. The intensive with natural rearing system (hereinafter, INS) and extensive system (hereinafter, ES) kids grew faster than intensive with artificial rearing (hereinafter, IAS) animals. IAS kids displayed the lowest real dressing percentages due to the higher development of empty gastrointestinal tract. The long leg and carcass were larger in ES kids than in kids from other management systems. The carcasses and cuts from INS and ES kids displayed more fat than those of IAS kids. Males grew faster than females. Carcasses in male kids showed a higher content of bones but a lower content of fat than carcasses in female kids. ES kids displayed stronger "pink" meats than INS and IAS animals. The IAS meat displayed the lowest capacity to retain water inside the muscle. Intramuscular fat deposits from kids reared under ES showed the lowest percentage of C14:0 fatty acids and the highest percentage of C18:1 fatty acid. ES produces similar goat kid meat as INS and IAS, but with a lower atherogenicity index. Growth, carcass quality, and meat quality data were collected. Canonical discriminatory analysis and cluster analysis of the entire meat production process and its stages were performed using the rearing systems as grouping criteria. All comparisons resulted in significant differences and indicated the existence

of three products with different quality characteristics as a result of the influence of the rearing system. Also, the Canonical Correlation analysis developed among groups of variables related to the growth, the carcass characteristics and meat characteristics shown important relation among the phases of production, processing and commercialization.

El origen de este estudio se encuentra en la situación actual del sector caprino en España, la cual está dirigiendo a ganaderos y empresarios hacia la búsqueda de sistemas más efectivos y con márgenes de beneficios que permitan la supervivencia de los diversos tipos de explotación que forman parte de este subsector. Es por ello que el Grupo de Investigación "Mejora y Conservación de los Recursos Genéticos de los Animales Domésticos" (AGR–218), del Programa Andaluz de Investigación (PAI), se planteó este proyecto de investigación relativo a las características de la canal y la calidad de la carne en cabritos de raza 'Murciano–Granadina'. Se trata de un proyecto acorde con la realidad, planteado y participado desde su origen por la 'Asociación Nacional de Criadores de Ganado Murciano–Granadino' y apoyado por la 'Sociedad Cooperativa Andaluza Los Filabres' ya que ambos aportan una visión del estado actual del mercado que permite hacer una investigación cuyos resultados resultan útiles para el sector.

La 'Murciano–Granadina' es una de las razas de tipo lechero más importantes, tanto a nivel regional, como nacional e internacional. Su buena aptitud lechera la ha colocado como una de las razas más preciadas del mercado y es por ello que resulta igualmente importante toda defensa de los sistemas de explotación en los que se desarrolla, toda vez que si éstos se mantienen, la raza gozará de una adecuada protección (Camacho y cols., 2000).

Aunque se trate de una raza fundamentalmente de aptitud lechera, no se debe descartar cualquier otra posible fuente de ingresos, que pueda ayudar a combatir la crisis actual a la que los ganaderos y el sector se enfrentan. Por ello, se debe intentar potenciar todos los productos y subproductos derivados de esta raza para asegurar su rentabilidad global.

Su potencial lechero está sobradamente demostrado, del mismo modo que lo está la calidad de su leche. Sin embargo, a la carne procedente de sus cabritos no se le ha prestado toda la atención que merecía. Sin duda, esto se debe a que en las explotaciones con cabras de raza 'Murciano–Granadina' el cabrito siempre ha sido considerado como un subproducto, un estorbo, un ladrón, un menoscabo de la producción lechera, ya que lo elemental de estas explotaciones es la producción láctea. Este trabajo de investigación se dirige a conocer y como consecuencia a potenciar el valor de este subproducto, ya que al definir sus calidades también se otorga a la carne de estos cabritos un valor añadido, su importancia en la explotación se incrementará y dará lugar a una mayor entrada de ingresos, lo cual beneficiará directamente al sector.

No se trata tan solo de revalorizar la carne procedente de estos cabritos, también resulta fundamental hacer una correcta diferenciación entre la carne procedente de los diversos sistemas de explotación. En la actualidad se pueden distinguir los siguientes sistemas de manejo: sistema intensivo con lactancia artificial, sistema intensivo con lactancia natural y sistema extensivo.

Esta distinción de sistemas puede llegar a afectar a la calidad de la carne, ya que tradicionalmente se ha entendido que la carne procedente de animales criados en sistemas extensivos posee unas características distintas a la que procede de los sistemas intensivos. Es por ello que se planteó un estudio que permitiera demostrar si en realidad existen variaciones en la calidad de la carne y la canal debidas al sistema en que se criaron los cabritos. Si se demostrase tal diferencia, será posible el establecimiento de una clasificación comercial del producto en función de su procedencia.

Asimismo, un completo estudio de la canal y de la carne permitirá iniciar el procedimiento de obtención de una Indicación Geográfica Protegida o cualquier otra marca de calidad diferenciada, lo cual concedería un valor añadido real al producto, constituyendo así una ayuda económica muy relevante en explotaciones tradicionalmente dedicadas de forma exclusiva a la producción de leche (Camacho, 2006).

En definitiva, se trata de un trabajo de investigación que persigue la revalorización del subproducto 'cabrito' en las explotaciones lecheras de raza 'Murciano–Granadina', en apoyo de su rentabilidad global.

Se debe indicar que aunque las cabras en Europa se usan principalmente para la producción de leche y queso, la carne de cabra en los países mediterráneos es una parte importante de la rentabilidad y de los ingresos de los ganaderos (Working Group FAO /

CIHEAM, 2002); es más, algunas organizaciones valoran la producción de carne procedente de sistemas de producción orgánica (Dubeuf y cols., 2004). La industria de la carne de cabra ha crecido recientemente (Omán y cols., 1999; Cameron y cols., 2001; Sahlu y cols., 2009), proporcionando nuevas oportunidades para obtener ingresos adicionales derivados de las operaciones de la agricultura diversificada.

La disminución de la rentabilidad de los sistemas tradicionales de producción agrícola representa un gran desafío para los países desarrollados debido al incremento en el costo de los combustibles fósiles, al aumento del coste de las semillas que se derivan a la producción de biocombustibles, a los elevados salarios y a la relevancia de los costes sociales (Camacho y cols., 2000). Las tendencias actuales sugieren que a día de hoy los productos lácteos y los productos cárnicos están perdiendo su cuota de mercado y que el declive continuará a menos que exista la adaptación comercial a las demandas del mercado sin perder la especificidad, la originalidad y autenticidad (Boyazoglu y Morand–Fehr, 2001). Afortunadamente, la carne de cabra es cada vez más popular debido a la positiva imagen medio ambiental de la ganadería caprina, los beneficios dietéticos y para la salud de su carne, la tendencia cultural de los consumidores hacia los alimentos naturales, las crisis de los alimentos, y la asociación de la carne de cabra con fiestas religiosas (Dubeuf y cols., 2004).

En los sistemas de manejo extensivos, la calidad y cantidad de forraje a menudo conduce a la insuficiencia nutricional (Ramírez y cols., 1996). Las cabras criadas en sistemas de manejo extensivos consumen la mayoría de los nutrientes que requieren del forraje de los pastos para así poder aumentar las ganancias de los productores; sin embargo, los sistemas de producción basados en pastos son limitados debido a la variación estacional en el contenido de nutrientes del forraje del pastizal. Por lo tanto, el pastoreo sin ningún otro aporte adicional no suele proporcionar una nutrición adecuada para los animales de rápido crecimiento (Wilkinson y Stark, 1987). En los sistemas intensivos, se ofrece una fuente de proteína y de energía (heno o concentrado) adicional para mantener un rendimiento del ganado aceptable, pero los costos asociados con esa dieta influyen en gran medida en el margen de beneficio de las empresas de carne de cabra. El sistema de manejo extensivo ha demostrado tener efectos beneficiosos sobre la calidad de la carne de los corderos (Carrasco y cols., 2009) y novillos (Fraser y cols., 2009), pero no hay información disponible sobre la calidad de la carne de cabrito producido en estas condiciones. Los efectos de la gestión ecológica en la calidad de la carne pueden respaldar la creación de etiquetas de protección que agreguen valor al producto y compensen el desequilibrio de beneficios del sistema de manejo extensivo. El tipo de sistema de gestión es uno de los factores principales que afectan a la calidad de la carne de cabritos. Así, parte de los objetivos de este estudio fueron determinar los efectos de los diferentes tipos de sistemas de gestión y el sexo sobre el crecimiento y calidad de la canal en cabritos de la raza de tipo lechero Murciano–Granadina, así como evaluar la influencia del tipo de sistema de gestión de calidad de la carne de cabrito.

La producción de carne se realiza en tres fases diferentes (Langreo, 2005). La calidad del producto final, la carne, vendrá determinada no sólo por la suma de los efectos aislados de todos los rasgos estudiados dentro de cada fase, sino también por las relaciones entre estos rasgos y cómo los grupos de rasgos interactúan dentro de cada fase y a través de las tres fases. La primera fase es la cría, y su atención se centra en los parámetros de crecimiento. La segunda, el sacrificio, está determinada por las características de la canal, integrada por la proporción de las piezas más valiosas y el contenido de tejidos. La tercera fase es la comercialización, que se define por la calidad de la carne, incluyendo los rasgos relacionados con las percepciones sensoriales. El análisis canónico discriminante se ha utilizado para clasificar a los animales sobre la base de algunos parámetros de calidad de la carne de cordero (Juárez y cols., 2008), pero no hay estudios que se hayan llevado a cabo en ganado caprino hasta el momento.

Aquí se ha desarrollado un amplio estudio del proceso de producción de carne de cabritos de raza Murciano–Granadina usando variables asociadas con las tres fases de la producción antes mencionadas. El estudio consistió en un análisis multivariado de profundidad, en el cual se emplean avanzados métodos como el análisis canónico discriminante, el análisis de conglomerados (o análisis cluster) y el análisis de correlación canónica (Everitt y Dunn, 1991), que no son de uso común en complejos estudios de producción de carne con variables que afectan a aspectos tan diversos del proceso de producción. Podría ser, pues, un modelo que se utilizara en la caracterización de la producción de carne de ganado caprino durante todo su proceso de producción, exportable a otras especies.

En definitiva, si el sector cuenta con un modelo apropiado para la caracterización de la producción de carne de ganado caprino durante su proceso de producción y, además, conoce los efectos de los diferentes sistemas de manejo y del sexo sobre el crecimiento, la calidad de la canal y la calidad de la carne de cabritos de la raza Murciano–Granadina, se facilitará la toma de decisiones en el seno del subsector.

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La hipótesis de esta tesis doctoral consiste en afirmar que el sistema de manejo en que los animales se producen influye en las características de la canal y de la carne de los cabritos de raza Murciano–Granadina.

Así, el objetivo genérico es definir científicamente la calidad de la carne y de la canal de los cabritos de raza Murciano–Granadina en sus distintos sistemas de manejo, para que sirva como base al desarrollo de alguna figura de protección de productos, lo que ofrecerá una vía para fortalecer la rentabilidad de la explotación lechera.

Para lograr esto se plantean los siguientes objetivos específicos:

1º. Analizar el efecto del sistema de manejo y del sexo en el crecimiento y en la calidad de la canal en cabritos de raza Murciano–Granadina. Este objetivo se aborda en el artículo titulado: "Effects of extensive system versus semi–intensive and intensive systems on growth and carcass quality of dairy kids".

2º. Conocer los efectos del sistema de manejo y del sexo en la calidad de la carne en cabritos de raza Murciano–Granadina. Este objetivo se aborda en el artículo titulado: "Effects of three management systems on meat quality of dairy breed goat kids".

3º. Estudiar las relaciones entre parámetros de crecimiento, de calidad de la canal y de la carne, así como su capacidad para definir productos diferenciados, con técnicas de análisis multivariado. Este objetivo se aborda en el artículo titulado: "Multivariate analysis of meat production traits in Murciano–Granadina goat kids".

III. COPIA COMPLETA DE LAS PUBLICACIONES

A continuación se reproducen una copia completa de los trabajos que han sido publicados o aceptados para su publicación. En el Anexo II figura el informe con el factor de impacto y cuartil del Journal Citation Reports (SCI y/o SSCI) del área en el que se encuentran las publicaciones o trabajos aceptados para su publicación.

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Effects of extensive system versus semi-intensive and intensive systems on growth and carcass quality of dairy kids[1]

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ABSTRACT - The aim of this research was to study the effects of three different management systems on growth and carcass quality of 61 Murciano-Granadina breed kids and their interaction with sex. In the extensive system, 21 kids were allocated to suckle from their dams on free-range pasture with no additional feedstuff. In the semi-intensive system, 20 kids were suckled from their dams and had access to alfalfa hay and cereal straw (no free-range pasture). In the intensive system, 20 kids were separated from the dams at birth and then fed with milk replacer and alfalfa hay. Animals were slaughtered at 7.00 ± 1.00 kg of average BW. The semi-intensive system and extensive system kids grew faster than intensive system animals (127, 113 and 96 g/d, respectively). Differences in energy intake may explain these differences. Intensive system kids displayed the lowest real dressing percentages, calculated as 100 × (hot carcass weight/empty body weight), due to high development of empty gastrointestinal tract. The long leg and carcass were larger in extensive system kids than in kids from other management systems, presumably due to high physical activity on the free-range pastures. The carcasses and cuts from semi-intensive system and extensive system kids displayed more fat than those of intensive system kids. Males grew faster than females (122 and 103 g/d, respectively). Carcasses in male kids showed a higher content of bones but a lower content of fat than carcasses in female kids. The extensive system is feasible for producing kid meat from a dairy breed.

Key Words: average daily gain, meat, Murciano-Granadina breed

Introduction

Although European goats are mostly used to produce milk and cheese, in Mediterranean countries goat meat is a profitable and important part of the income of breeders (Working Group FAO/CIHEAM, 2002), and some organizations value goat meat production from traditional production systems (Dubeuf et al., 2004). Although goat production in the United States has historically been a low-labor business with little emphasis on animal production and management practices, the meat-goat industry has recently grown (Cameron et al., 2001; Oman et al., 1999; Sahlu et al., 2009), providing new opportunities for additional income derived from diversified farming operations. This rising interest/demand for goat meat in the United States has possibly been a result of increased ethnic diversity. Worldwide pork and beef are mainly consumed in urban areas, but goat meat is mainly consumed in rural areas, and most meat is sold at local or regional markets for domestic consumption. However, goat meat is becoming increasingly popular because of its positive ecological image, dietetic and health benefits, the cultural tendency of consumers towards natural foods, recent food crises, and the association of goat meat with religious holidays (Dubeuf et al., 2004). The effect of the type of management system on the carcass quality of goats has been investigated in a limited number of studies. Extensive meat goats are fed on forages, increasing the profit to the producers; pasture based production systems are limited, however, because of seasonal variations in nutrient content of the pasture forage. This often means that the pasture by itself does not provide adequate nutrition for quickly growing animals (Wilkinson & Stark, 1987). In intensive with artificial or natural rearing systems, an additional protein and energy source (hay or concentrate) is offered to maintain acceptable goat performance. Thus, the objectives of this study were to determine the effects of the different types of management systems and sex on growth and carcass quality in dairy goat kids.

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Material and Methods

The experiment started in January 2007 and took place in Granada, located at 37º11' N latitude and 3º35' W longitude, 570 m above the sea level and under mediterranean ecosystem.

Sixty-one Murciano-Granadina kids (28 females, 33 males) from the herd located in the Farm Research of Diputación de Granada in Albolote (Granada, Spain) at 37º 14' latitude and –3º 39' loongitude, 655 m above mean sea level, were raised under 3 different management systems (extensive, semi-intensive, and intensive) all located in the Farm Research of Diputación de Granada. Animal handling was according to the guidelines of the EC Directive 86/609/ EEC (European Communities, 1986).

The 21 kids (9 females, 12 males) in the extensive system suckled directly from dams and were raised on a free-range pasture containing mostly wheat (*Triticum Sativum Lam. T. Vulgare*), oat (*Avena sativa*), and chickpeas (*Cicer arietinum*), with no additional feedstuff. At night, they were housed with their dams in a stable. Kids (9 females, 11 males) in the semi-intensive system suckled directly from dams and had access to alfalfa hay and cereal straw. The semi-intensive system kids did not have access to a pasture. The 20 kids (10 females, 10 males) in the intensive system were separated from dams after birth, housed in an artificial rearing room, and fed colostrum for the first 2 days, as described by Castro et al. (2005). Then, kids had free access to milk replacer 24 h a day (Univet lambs and kids 60, Nutral S.A., Madrid, Spain; 6.00% ash, 0.04% cellulose, 24.00% protein , and 24.50% fat on dry matter), which was sucked from a teat connected to a unit for feeding liquid dieta. This feeding regimen was supplemented with alfalfa hay. Kids from all 3 systems had free access to water at all times.

Kids were weighed at birth and then weekly until slaughter with a digital hook weight (PCE-HS 50, maximum = 50 kg, e = 20 g, PCE Group Ibérica, Albacete, Spain).

Kids were slaughtered at Los Filabres SCA when their body weight was 7.00 ± 1.00 kg. Kids were fasted with free access to water during the 24 hours before slaughter. The slaughter procedure and carcass definition were as described by Colomer-Rocher et al. (1987). Hot (after slaughter) and chilled (after 24 h chilling at 4 °C) carcass weight (PCE-HS 50, maximum = 50 kg, e = 20 g, PCE Group Ibérica, Albacete, Spain) and weights of the head, skin, heart, liver, lungs and trachea, kidney, full and empty gastrointestinal tract (gastrointestinal content was determined as the difference between them), and spleen were recorded using electronic weights (G-310, maximum = 15 kg, e = 5 g, Dibal S.A., Bilbao, Spain; and Tefal model Gourmet, maximum = 5 kg, e = 1 g, Groupe SEB Ibérica, Barcelona, Spain). Empty body weight (EBW) was calculated by subtracting the weight of the gastrointestinal contents from fasted body weight (FBW). Dressing carcass percentages were calculated using chilled carcass weight (CCW), hot carcass weight (HCW), FBW, and EBW. The commercial and real dressing percentages (CDP and RDP respectively) were calculated as follows:

$$CDP = 100 \times (CCW/FBW)$$

$$RDP = 100 \times (HCW/EBW)$$

Carcass measurements included long leg length from the symphysis pubis to the tarsal–metatarsal joint (McMeekan, 1939); carcass length, from the symphysis pubis to the anterior edge of the middle of the first rib (Pálsson, 1939); maximum width, between femur trochanters (Pálsson, 1939); and maximum distance, between the sternum and the sixth thoracic vertebra (Pálsson, 1939).

After chilling, carcasses were split down. The left side was divided into five prime cuts (neck, flank, ribs, shoulder, and long leg) and three minor cuts (kidney, kidney fat, and tail), as described by Colomer-Rocher et al. (1987). Prime cuts were weighed (Tefal model Gourmet, maximum = 5 kg, e = 1 g, Groupe SEB Ibérica, Barcelona, Spain) and dissected into separable tissues (subcutaneous and intermuscular fat, lean, bone). The separable tissues were weighed with the same weight described above.

Two-way ANOVA analysis (SAS Institute Inc., 1999-2001, v. 8.2. for Windows, Cary, North Carolina, USA) was performed including the fixed effects management system and sex, and the interaction between them. Finally, a Duncan post-Hoc test (SAS Institute Inc., 1999-2001, v. 8.2. for Windows. Cary, North Carolina, USA) was used to determine in which factor level the differences were located.

Results and Discussion

The results of factorial ANOVA, including the fixed effect of the management system and the sex as well as their interaction, applied to the weight at birth and at 7, 14, 21, and 28 days old, and the ADG (average daily gain) from birth to slaughter, showed statistical differences between the management systems (Table 1). The results also showed that there were no significant differences between sexes in relation to growth.

Statistical differences between the three management systems were found for birth weight. Kids managed under semi-intensive (3.52 kg) and intensive system (3.54 kg) were heavier at birth than kids managed under extensive system (3.05 kg). A better diet for the dams in the semi-intensive system and intensive system may explain these differences in birth weight. It has been demonstrated that the diet of

Table 1 - Effect of management system and sex on estimated weights at different ages and average daily gain

Item	Management system			Sex		SEM
	Extensive	Semi-intensive	Intensive	Male	Female	
Weight at birth, kg	3.05b	3.52a	3.54a	3.71	3.13	0.11
Estimated weight, kg						
at 7 days	3.51b	3.91a	3.33b	3.98	3.37	0.08
at 14 days	4.25ab	4.37a	3.95b	4.53	3.86	0.09
at 21 days	5.08b	5.71a	4.86b	5.77	4.87	0.14
at 28 days	6.23b	6.96a	5.89b	6.92	5.87	0.15
Average daily gain, g						
0-28 days	113.58a	127.58a	96.02b	122.26a	103.53b	4.62

Means followed by different letters on the same row differ (P<0.05) significantly.
SEM = standard error of the mean.

pregnant females affects the birth weight of kids, and dams from the semi-intensive system and intensive system had free access to feedstuff (Tag-Eldin, 2000). Camacho et al. (2009) did not find statistical differences in birth weight for kids from Blanca Serrana Andaluza breed goats born in extensive or intensive system; however, this is a meat-specialized breed, and the animals were not milked. Thus, the Blanca Serrana Andaluza goats were able to accumulate fat reserves that did not result in differences in birth weight.

At 7, 21, and 28 days of age, semi-intensive system kids were heavier than intensive system and extensive system kids. At 14 days of age, semi-intensive system kids were heavier than intensive system kids. The intensive system kids displayed the lowest estimated weights at all ages tested. The intensive system kids received milk replacer as described in Material and Methods, and some authors (Argüello et al., 2004) have reported lower weight in kids fed milk replacer relative to goat milk due to low energy and protein intake.

Two possibilities can account for the statistical differences between semi-intensive system and extensive system estimated weights. As described in Material and Methods, extensive system animals went to the pasture daily with dams, which increased their maintenance requirements. It is well established that grazing animals expend more energy than animals in confinement (Lachica & Aguilera, 2005), for two main reasons. First, in the stall, food is offered in a partially processed form, which makes it easier to ingest and digest. In addition, an animal in a stall does not have to move to search for food. Second, as Blaxter (1967) suggested, the high maintenance requirements of sheep in pastures may be due to an increased cost of body movement in the pasture, especially the cost of walking and harvesting herbage. On the other hand, milk quality and quantity can be affected by the nutritional status of the dam (Morand-Fehr, 2005). As extensive system goats did not receive any feed supplements, their milk quality and quantity were lower than in semi-intensive system goats, and thus, these kids showed a lower estimated weight at 28 d. In addition, Johnson & McGowan (1998) found statistical differences between young goats from a native Florida breed reared in intensive and semi-intensive systems. At the same age at slaughter, goats raised in an intensive system had heavier slaughter weights than goats raised in a semi-intensive system.

As shown by ADG, semi-intensive system and extensive system kids grew faster than intensive system kids. Although the measured ADG for semi-intensive system kids was 10.97% higher than for extensive system kids, this difference was not statistically significant due to the high coefficient of variation. Similarly to the explanation for estimated weights, semi-intensive system kids received more and better quality milk than extensive system kids due to supplementation of the dam's feedstuff and no energy expenditure to move to pasture (Blaxter, 1967; Lachica & Aguilera, 2005; Morand-Fehr, 2005). The lower protein and energy intake by intensive system kids fed with milk replacer may be the reason why these kids had the lowest ADG. In contrast, Camacho et al. (2009) did not find statistical differences in daily gains with respect to their Blanca Serrana Andaluza goats reared under extensive or intensive management systems. The differences between the results of Camacho et al. (2009) and our current study may lie in the different breed types; the current study was performed using dairy goats, and the previous one focused on meat goats.

No statistical differences were observed between sexes at any tested age, although a trend towards heavier weights in males was observed. The kids in the current study were slaughtered at low FBW as is the usual practice in Spain. Thus, low FBW may explain the absence of statistical differences between sexes, in addition to the high standard error of the mean. Consistent with our observations, Argüello et al. (2004) did not find statistical differences between sexes in ADG in another dairy Spanish breed (Majorera breed) slaughtered at the same weight. Peña et al. (1994) did not find statistical differences by sex in Florida Sevillana dairy breed goats. In meat breeds, Camacho et al. (2009) and Costa et al. (2010) did not find statistical differences in ADG with respect to kid sex in Blanca Serrana Andaluza goats.

Male and female kids (Table 1) showed significant differences related to ADG. Males grew faster than females. In goat species, differences in ADG between males and females have sometimes been reported (Argüello et al., 2004) and sometimes they have not (Mavrogenis, 1983). Number of animals, breed effect, trial length, and many other factors may explain the controversial observations.

FBW (Table 2) was not statistically different between the three management systems, but extensive system kids tended to have a lower FBW than semi-intensive system and intensive system kids. Semi-intensive system and extensive system animals were slaughtered before intensive system kids because they need less time to weight 7.00 ± 1.00 kg. HCW ranged from 3.64 to 4.09 kg, with semi-intensive system kids being heavier than extensive system and intensive system kids. The weight loss by evaporation on carcasses is due to the effects of chilling averaged 4.10 % for all groups, which is consistent with that reported by Argüello et al. (2007) with similar FBW. Similar results among management systems were observed for CCW. The differences in HCW and CCW between semi-intensive system and extensive system kids were due to the lower FBW observed in extensive system animals. The differences between semi-intensive system and intensive system kids were due to a greater contribution of the weight of the gastrointestinal tract to FBW in intensive system kids.

Semi-intensive system kids displayed the greatest CDP values. Full gastrointestinal tract and skin percentages of FBW were greater in intensive system kids, which reduced the CDP in these animals relative to semi-intensive system kids. Consistent with the observation by Argüello et al. (2007), at similar FBW, kids fed milk replacer showed greater gastrointestinal tract development than kids nursed by dams because they began to eat alfalfa hay earlier, as a consequence of the fact that milk replacer did not provide all nutritional requirements. Extensive system kids showed lower CDP than semi-intensive system kids because the head and full gastrointestinal tract percentages were greater in extensive system kids. Similarly, the RDP for semi-intensive system kids was greater than for intensive system and extensive system kids. Because extensive system animals had greater gastrointestinal tract content, the RDP of these animals resulted in significantly greater values than intensive system kids. Zurita-Herrera (2007) found statistical differences in the CDP between Blanca Serrana Andaluza meat breed kids of the intensive system (47.76%) and extensive system (45.35%), but there were no statistical

Table 2 - Effects of management system and sex on fasted body weight, age at slaughter, carcass weight and dressing percentages, linear dimensions and prime cuts percentages

Item	Management system			Sex		SEM
	Extensive	Semi-intensive	Intensive	Male	Female	
FBW, kg	6.78	7.40	7.11	7.19	6.98	0.09
Age at slaughter, days	33.87a	33.76a	38.37b	35.09a	46.18b	1.09
Carcass weights						
Hot carcass wt, kg	3.64b	4.09a	3.72b	3.86	3.76	0.05
Cold carcass wt, kg	3.47b	3.92a	3.59b	3.72	3.59	0.05
Carcass dressing percentages						
Commercial dressing %	51.00b	52.87a	50.98b	51.70	51.45	0.24
Real dressing %	56.10b	57.34a	55.27c	56.29	56.31	0.23
Linear dimensions						
Long leg length, cm	25.75b	23.91a	23.85a	24.91	24.07	0.18
Carcass length, cm	41.01b	38.96a	40.59b	40.02	40.42	0.24
G[1], cm	9.24a	9.44a	8.87b	9.10	9.29	0.07
Th[2], cm	15.21	14.94	14.96	15.07	15.01	0.08
Prime cut percentages						
Shoulder	17.38b	16.18a	16.78ab	16.92	16.64	0.10
Leg	22.39	21.98	22.69	22.04	22.72	0.14
Ribs	28.04b	31.90a	29.86c	29.99	29.81	0.29
All cuts	67.81b	70.06a	69.33ab	68.95	69.16	0.40

Means followed by different letters on the same row differ significantly (P<0.05).
[1] Maximum width between femur trochanters.
[2] Maximum distance between sternum and sixth thoracic vertebra.
SEM = standard error of the mean.

differences in the RDP. Those results are opposite to the ones observed in present study, but differences in breed aptitude may explain this controversy.

Extensive system kids had the greatest long leg length (Table 2), and no significant differences were observed between semi-intensive system and intensive system animals. Animals raised in small pens have a shorter long leg length (Borghese et al. 1990); in the present study, extensive system kids moved to the pasture daily, and thus would be expected to have a greater long leg length. Semi-intensive system kids showed the shortest carcass, but no significant differences were observed between extensive system and intensive system animals. These results may be because extensive system animals moved to the pasture daily, and intensive system animals were the oldest. Extensive system kids and semi-intensive system kids had the greatest maximum width between femur trochanters. No statistical differences between the management systems were observed for the maximum distance between sternum and sixth thoracic vertebra. Similar results were reported by Zurita-Herrera (2007) using Blanca Serrana Andaluza meat breed, in which statistical differences were found in the carcass length between the extensive system (54.10 cm) and intensive system (52.20 cm). Some authors have reported that carcasses become more compact with increased age at slaughter (Anous & Mourad, 2001; Attah et al., 2004; Marichal et al., 2003; Mourad et al., 2001).

For prime cut percentages (Table 2), the shoulder percentage of HCW was the lowest in the semi-intensive system group. Although statistical differences were observed between semi-intensive system and extensive or intensive system kids, these results were not biologically relevant. There was no effect of management system on long leg percentage of HCW. Ribs in semi-intensive system kids significantly contributed to HCW more than ribs in extensive system or intensive system kids. There were no differences between extensive system and intensive system kids with respect to the contribution of ribs to HCW. In agreement with our results, Zurita-Herrera (2007) showed that meat breed kids from an intensive system had a greater percentage of ribs (25.00%) than kids from an extensive system (22.50%). The contribution of the high value cuts of semi-intensive system kids to HCW was significantly greater than that in extensive system or intensive system animals.

The sex effects (Table 2) were only significant for age at slaughter because the FBW was fixed and the ADG for females was lower than in males. Similar findings were reported by Zurita-Herrera (2007) using Blanca Serrana Andaluza meat goats.

No significant differences were observed between management systems in blood, fore and hind feet, head, full gastrointestinal tract, gastrointestinal content, liver, urinary bladder, male genitals, spleen, right kidney, lungs and trachea, heart, and swindle (Table 3). Intensive system kids were reared indoors with no bedstraw, unlike semi-intensive system and extensive system animals. These management differences may explain the significantly greater skin percentage observed in intensive system animals because the absence of bedstraw caused a greater skin development as a way to protect themselves from low temperatures. As described by Argüello et al. (2007), intensive system kids displayed the greatest percentage of empty gastrointestinal tract due to their starting to feed on alfalfa hay sooner than the others.

Table 3 - Effects of management system and sex on different noncarcass components (as a percentage of fasted body weight)

Item, %	Management system			Sex		SEM
	Extensive	Semi-intensive	Intensive	Male	Female	
Blood	4.40	3.92	3.67	5.18	4.86	0.23
Skin	8.48a	8.54a	9.38b	8.88	8.69	0.09
Fore and hind feet	4.21	4.26	4.79	4.63	4.17	0.07
Head	7.47	7.25	7.95	7.50	7.62	0.14
Full gastrointestinal tract	13.30	13.09	14.80	13.13	14.42	0.25
Gastrointestinal tract content	4.45	3.66	3.86	3.86	4.63	0.18
Empty gastrointestinal tract	8.84a	9.43ab	10.28b	9.27	9.79	0.15
Liver	2.32	2.47	2.77	2.50	2.54	0.04
Urinary bladder	0.23	0.19	0.26	0.24	0.21	0.02
Masculine genitals	0.36	0.16	0.24	0.26	-	0.01
Spleen	0.28	0.26	0.24	0.26	0.26	0.01
Right kidney	0.53	0.50	0.50	0.52	0.50	0.01
Lungs and trachea	2.49	2.03	2.36	2.33	2.26	0.05
Heart	0.68	0.74	0.65	0.70	0.68	0.01
Swindle	0.25	0.19	0.28	0.27	0.21	0.02

Means followed by different letters In the same row differ significantly (P<0.05).
SEM = standard error of the mean.

For half-carcass fat deposits (Table 4), the subcutaneous fat percentages of semi-intensive system and extensive system kids were significantly greater than in intensive system kids. For half-carcass intermuscular fat, the semi-intensive system percentage was the greatest. The contribution of fat to joint weight of ribs and flanks was statistically significant. Thus, semi-intensive system kids showed a significantly greater fat contribution than extensive system or intensive system animals. The low subcutaneous fat percentages in intensive system kids may be due to the relatively low energy intake by goat kids fed milk replacer (Argüello et al., 2007; Morand-Fehr et al., 1986). Zurita-Herrera (2007) reported a greater percentage of perirrenal and pelvic fat in Blanca Serrana Andaluza meat goat kids reared in an intensive system (3.46%) than kids reared in an extensive system (1.11%). Other researchers have noted that goats fed a complete concentrate ration exhibit increased carcass fat deposition, compared with browsing or grazing animals (Ash & Norton, 1987; McGregor, 1985). Joy et al. (2008) demonstrated that intermuscular fat deposits were lower in lambs pastured continuously than in lambs housed indoors, which is in agreement with our findings in extensive system kids that moved to the pasture daily.

Intermuscular and subcutaneous fat percentages on half carcasses or cuts were similar to those described for other dairy breed goats (Argüello et al., 2007). Bone half-carcass and cut percentages were not affected by the type of management system because the wave of bone development had been completed (Hammond, 1966). Bone percentages in half carcasses and cuts were not affected by the type of management system, and the results were according to other dairy breeds kids (Argüello et al., 2007). In contrast to bone percentage, lean percentages were affected by the management system in half carcasses, long legs, ribs, and flank cuts (Table 4). Intensive system kids displayed the greatest lean half-carcass percentage. Long legs and rib cuts showed lower lean percentages in semi-

Table 4 - Effects of management system and sex on half-carcass and prime cuts' composition

	Management system			Sex		
Item, %	Extensive	Semi-intensive	Intensive	Male	Female	SEM
Total half-carcass						
Subcutaneous fat	3.07a	3.39a	1.81b	2.67	2.92	0.16
Intermuscular fat	1.74b	3.45a	2.21b	2.30	2.92	0.15
Bone	32.48	31.59	31.31	32.56a	30.92b	0.28
Lean	55.89b	54.07a	57.38c	55.25a	56.40	0.33
Shoulder						
Subcutaneous fat	1.66	1.11	1.45	1.48	1.34	0.14
Intermuscular fat	0.56	0.83	0.59	0.57	0.77	0.06
Bone	35.40	35.96	34.45	35.61	34.87	0.36
Lean	55.21	54.34	55.77	54.59	55.71	0.29
Long leg						
Subcutaneous fat	3.81a	3.45a	1.95b	2.84	3.37	0.21
Intermuscular fat	0.92	0.91	0.64	0.78	0.87	0.07
Bone	24.72	25.13	24.02	25.20a	23.95b	0.29
Lean	65.11a	64.91a	67.93b	65.78	66.19	0.42
Ribs						
Subcutaneous fat	2.38b	3.51a	1.67b	2.40	2.65	0.23
Intermuscular fat	2.81b	5.25a	3.30b	3.49	4.13	0.23
Bone	35.05	31.87	32.46	34.46	31.62	0.45
Lean	49.74a	48.02a	52.00b	49.21	50.75	0.43
Neck						
Subcutaneous fat	1.23	2.55	0.80	1.36	1.72	0.34
Intermuscular fat	2.76	3.53	2.59	3.05	2.85	0.28
Bone	29.73	29.70	30.77	30.40	29.66	0.62
Lean	56.85	54.73	55.47	55.45	56.01	0.84
Flank						
Subcutaneous fat	7.22a	7.70a	3.37b	6.68	5.45	0.50
Intermuscular fat	5.70b	8.61a	5.70b	6.79	6.52	0.38
Bone	36.94	39.19	39.77	38.82	38.34	0.68
Lean	43.98b	40.32a	45.71b	42.34	44.54	0.65

Means followed by different letters on the same row differ significantly (P<0.05).
SEM = standard error of the mean.

intensive system and extensive system kids than in intensive system kids. Similar to the previously mentioned cuts, semi-intensive system kids presented the lowest lean percentage in flanks. The lean percentage in shoulder and neck was not affected by the type of management system. Tissue composition was expressed as the percentage of each tissue of the total cut weight. Thus, intensive system kids displayed low fat levels in the carcass, increasing the lean percentages. Similar results in dairy breeds have been reported by Argüello et al. (2007). In addition to the previous explanation, Atti et al. (2004) observed comparable bone carcass percentages when CP intake increased, but, conversely, the proportions of fat and muscle were affected by the CP intake level. Kids in Atti et al. (2004)'s study fed a medium protein diet had relatively more muscle and lower fat than those receiving a high protein-content diet.

Female half carcasses were fatty (no significant effect), less bony, and leaner than males. Significant differences were observed in the bone percentage of the long leg, in which males were bonier than females. Some researchers have reported that female goat carcasses have a greater fat percentage than either castrated or intact males (Colomer-Rocher et al., 1992; Hogg et al., 1992; Warmington & Kirton, 1990). Zurita-Herrera (2007) found that female Blanca Serrana Andaluza meat breed goats accumulated more total fat than males.

Conclusions

Extensive system represents a realistic possibility to produce kid meat from a dairy breed. Further studies must assess the economic feasibility and meat quality of kids reared under extensive system management. Although semi-intensive and extensive systems produced some minimal differences in carcass quality, the carcasses produced by semi-intensive and extensive systems were quite similar. The use of intensive system for kid carcass production when pastures are available is recommended if milk is to be transformed into cheese with high value added. Differences between males and females were only found for growth and tissue composition, which suggests that farmers can rear males and females together with no expected differences in carcass quality.

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Effects of three management systems on meat quality of dairy breed goat kids

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The effect of three management systems on meat quality of 61 goat kids was determined. Kids from the extensive management system displayed stronger "pink" meats than animals from intensive systems with natural and artificial rearing management. The type of management system did not affect the pH, chemical composition and sensorial evaluation. Intensive combined with artificial rearing management system meat displayed the lowest capacity to retain water inside the muscle. Intramuscular fat deposits from kids reared under extensive management system showed the lowest percentage of C14:0 fatty acids and the highest percentage of C18:1 fatty acid. A strong influence of physical activity and trough grazing modulated the fatty acid profile in muscle of kids reared under an extensive management system, producing healthier meat relative to intensive with natural and artificial rearing management systems, as reflected by the fact that the lowest atherogenicity index was measured in intramuscular fat from kids reared under extensive management system. An extensive management system produces similar goat kid meat as intensive with natural and artificial rearing management systems, but with a lower atherogenicity index.

Keywords: fatty acid; chemical composition; atherogenicity index

1. Introduction

Current trends suggest that present day dairy and meat products are losing their market share and that the decline will continue unless there is commercial adaptation to market demands without losing specificity, originality and authenticity (Boyazoglu and Morand-Fehr 2001). However, goat meat is becoming increasingly popular because of the positive environmental image of goat ranching, the meats' dietetic and health benefits, the cultural tendency of consumers towards natural foods, recent food crises and the association of goat meat with religious celebrations (Dubeuf et al. 2004). Due to the relationship between high-fat diets and heart disease, consumer interest in the fat content and fatty acid composition of foods has grown in recent years (Scollan et al. 2006).

The relationships between dietary fat and the incidence of lifestyle diseases, particularly coronary heart disease, are well established and this has contributed towards the development of specific guidelines from the World Health Organization in relation to fat in the diet (WHO 2003). It is recommended that total fat, saturated fatty acids (SFA), n-6 polyunsaturated fatty acids (PUFA), n-3 PUFA and trans-fatty acids should contribute <15–30%, <10%, <5–8%, <1–2% and <1% of total energy intake, respectively. Reducing the intake of SFA (which are known to raise total and low-density lipoprotein (LDL) cholesterol) and increasing the intake of n-3 PUFA is particularly encouraged. In addition, the atherogenicity index has to be taken into account. The increased levels of C12:0 and C14:0 without an increasing in the total saturated fatty acid content provided an increase in atherogenicity index (Mariniello et al. 2011), and according to Hu et al. (2001) these acids are crucial for high levels of LDL cholesterol and the blood plasma in humans.

Due to the fact that in many European countries goat meat is very poorly valued (Dubeuf et al. 2004), few large-scale goat meat production systems exist, even around the Mediterranean. Due to this marginalisation, there are not many studies on goat products and most of them belong to milk production and especially to milk derivatives. Presently, the economical crisis is affecting the general commerce and alternative sources of added values are in mind of the sector. There is evidence that diet influences human health has promoted a new, blooming market – the functional foods market (Madruga and Bressan 2011). The functional food market is now characterised by bioactive compounds or ingredients. According to Vandendriessche (2008), meat and

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meat-derived products should incorporate concepts and innovations in order to reduce the fat used in formulae. It could be that meat from kids when consumed could have beneficial effects on health (reducing atherogenicity index, for example). In addition, goats deposit more internal fat and less subcutaneous and intramuscular fat compared with sheep (Colomber-Rocher et al. 1992). Hence, consumers are interested in goat meat as a source of relatively lean meat, especially in developed countries with a high incidence of cardiovascular diseases (Banskalieva et al. 2000).

Thus, the aim of this study was to evaluate the influence of the type of management system on goat kid meat quality as well as to assess the fatty acid profile of the extensive kid meat, dealing with differences in the fatty acid composition (particularly with regard to long chain fatty acids) of the extensive meat with intensive with artificial and natural rearing systems.

2. Material and methods

2.1. Animals and management systems

Sixty one Murciano-Granadina kids (28 females, 33 males) from the herd located in the experimental farm of Diputación de Granada (Granada, Spain) were raised under three different management systems (extensive, intensive with natural rearing and intensive with artificial rearing) from birth to their slaughtering at around 34–38 days old and when they reached 7 ± 1 kg of live weight. The 21 kids (nine females, 12 males) in the extensive management system (E) suckled directly from dams and were raised on a free-range pasture containing mostly wheat *(Triticum Sativum Lam. T. Vulgare)*, oat *(Avena sativa)* and chickpeas (*Cicer arietinum*), with no additional feedstuff. At night, they were housed with their dams in a stable. Kids (nine females, 11 males) in the intensive with natural rearing management system (IN) suckled directly from dams and had access to alfalfa hay and cereal straw. The IN kids did not have access to a pasture but could exercise freely. The 20 kids (10 females, 10 males) in the intensive with artificial rearing management system (IA) were separated from dams afterbirth, housed in a nursing parlour, and fed colostrum for the first 2 days, as described by Castro et al. (2005). Subsequently, kids had free access to milk replacer from 9 am to 4 pm (Univet lambs and kids 60, Nutral S.A., Madrid, Spain; ash 6.00%, cellulose 0.04%, protein 24.00% and fat 24.50% on dry matter) that was distributed by a nursing device. This feeding regimen was supplemented with alfalfa hay. Kids from all three systems had free access to water at all times.

2.2. Slaughtering procedure

Animals were slaughtered according to the guidelines of the Council Directive 86/609/EEC (European Communities 1986). They were slaughtered at Los Filabres S.C.A. when their body live weight (BW) reached 7 ± 1 kg. Kids from E and IN took 34 days to reach that BW, and kids from IA took 38 days to reach it. Kids fasted with free access to water during the 24 h before slaughter. The slaughter procedure and carcass definition were as described by Colomer-Rocher et al. (1987). Immediately after dressing, the carcass comprising the body after removing skin, head, forelimb (disjointed at the carpus), hind-limb (disjointed at the tarsus) and viscera was prepared. The kidneys and kidney and pelvic fat were retained in the carcass, and the testes and scrotal fat were removed as described by Colomer-Rocher et al. (1987). After 24 h of chilling (4°C), carcasses were split down the dorsal midline. The left side was divided into five primal cuts (neck, flank, ribs, shoulder and long leg) as described by Colomer-Rocher et al. (1987). Hot (after slaughter) and chilled (after 24 h chilling at 4°C) carcass weight (PCE-HS 50, maximum = 50 kg, e = 20 g, PCE Group Ibérica, Albacete, Spain) and weights of the head, skin, heart, liver, lungs and trachea, kidney, full and empty gastrointestinal tract (gastrointestinal content was determined as the difference between them) and spleen were recorded using electronic weights (G-310, maximum = 15 kg, e = 5 g, Dibal S.A., Bilbao, Spain; and Tefal model Gourmet, maximum = 5 kg, e = 1 g, Groupe SEB Ibérica, Barcelona, Spain). Empty body weight (EBW) was calculated by subtracting the weight of the gastro-100 intestinal contents from fasted body weight (FBW). Dressing carcass percentages were calculated using chilled carcass weight (CCW), hot carcass weight (HCW), FBW and EBW. Samples of *longissimus thoracis et lumborum* (LTL), *triceps brachii* (TB) and *semimembranosus* (SM) muscles were then removed. Intermuscular and subcutaneous fat samples were obtained from the shoulder. All samples were frozen (−20°C) during 7 days until analysis.

2.3. Meat quality attributes

Meat quality traits were measured in different muscles (LTL, TB and SM) because there were not enough muscle samples to carry all of the analysis using just one muscle. Muscle pH was measured in LTL, TB and SM using a Crison 166 pH metre with a combined electrode (Crison instruments S.A., Barcelona, Spain) by inserting into selected muscles immediately after slaughter and 24 h after chilling. Muscle colour was measured at the same time and in the same muscles (LTL, TB and SM) as pH using a Minolta CR200 Chroma-meter (Konica Minolta Sensing, Inc., Osaka, Japan) in the C.I.E. L*a*b* space (C.I.E. 1986), in which L* indicates relative lightness, a* indicates relative redness and b* represents relative yellowness.

The water holding capacity was measured according to Grau and Hamm (1953) on SM muscle. The SM muscle samples were sealed in a vacuum bag and cooked in a water bath at 75°C for 45 min to measure cooking losses. Cooked muscle cores (1 × 1 cm and at least 3 cm long) were cut parallel to the muscle fibers, and shear force values were recorded using an Instron Universal Testing Machine with a Warner-Bratzler shear force (WBSF) device (Instron, Barcelona, Spain).

Proximate analysis (moisture, protein, fat, collagen and soluble collagen) was performed on LTL according to AOAC (1984) procedures 24003, 13032 and 2057. Frozen powdered samples (4 g) were heated for 70 min at 77°C in one fourth strength Ringer's solution and separated into supernatant and residue fractions following the procedure of Hill (1966). Each fraction was individually hydrolysed in 6N HC1 for 6 h at 1 atm pressure and 102°C. The hydroxyproline content was determined as outlined by Bergman and Loxley (1963). Collagen content (mg/g, fresh tissue basis) was computed by multiplying the hydroxyproline content of the insoluble portion by 7.25 (Goll et al. 1964) and that of the soluble portion by 7.52 (Cross et al. 1973). The collagen content of the supernatant fraction expressed as a percentage of total collagen constituted percentage soluble collagen as specified by Hill (1966). Fatty acid composition was determined according to Granados (2000).

Fat was extracted from TB and subcutaneous and intermuscular fat as described by Folch et al. (1957). Briefly, fatty acids were separated before derivatisation (ISO Norm 5509, 2000) in a gas chromatograph (Model HP 5890 Series II GC; Hewlett-Packard, Avondale, PA) equipped with a flame ionisation detector and a phenyl-methyl-siloxane (cross-linked at 5%) capillary column (30 m long, 0.25 mm internal diameter, film thickness of 0.25 μm). The detector and the injector were maintained at 280°C. The carried gas was helium at a flow rate of 1 ml/min and a division ratio of 100:1.

The atherogenicity index was calculated using the equation developed by (Ulbricht and Southgate 1991):

$$\text{Atherogenicity index} = (C12:0 + (4 \times C14:0) + C16:0)/(MUFA + PUFA)$$

where MUFA is monounsaturated fatty acids and PUFA is polyunsaturated fatty acids.

2.4. Sensory panel evaluation

Samples of TB were cooked in plastic bags in a water bath at 75°C for 45 min. Panelists evaluated samples using a five-point descriptive scale for taste (1 = very bad, 2 = bad, 3 = regular, 4 = good, 5 = very good) according to UNE 87-005-92 (AENOR 1992).

2.5. Statistical analysis

A two-way ANOVA model (SAS Institute Inc., 1999–2001, v. 8.2. for Windows. Cary, North Carolina, USA) including the fixed effects of the management system and sex was performed and described the interaction between them. A Duncan post-hoc test of mean homogeneity (SAS Institute Inc., 1999–2001, v. 8.2. for Windows. Cary, North Carolina, USA) was developed to test the individual separation of means. Threshold level of probability to declare the statistical significance of the difference between pairs of means was $P < 0.05$.

3. Results and discussion

The type of management system affected some colour parameters determined in the three different muscles (Table 1). L* values in SM, LTL and TB were not affected by the different management systems (Table 1), and values were in agreement with those established for others dairy goat breeds (Argüello et al. 2005). Statistical analysis showed that SM redness was the lowest with IN, LTL redness was the highest with E, and no system management effects were observed for the TB. *SM* yellowness was the lowest with IA, and no system management effects were observed on the LTL and on the TB samples. Extensive system dams had free access to pasture during the day, and thus rich Fe pasture intake was greater than in other management systems. Johnson and McGowan (1998) observed the diet/management effects (intensive and semi-intensive) on carcass attributes and meat quality of young goats, and found that lean colour in the LTL was not affected by diet/management, but Schroeder et al. (1980) reported that concentrate feeding of beef produced a lighter lean colour, which could be due to because these beefs had no access to rich Fe pasture intake as a result of not being raised under extensive management. In addition, higher redness values have been correlated with grazing in studies with lambs (Ripoll et al. 2008). Ripoll et al. (2008) reported that increases in physical activity and greater carotenoid intake (characteristic of E) correlate with higher redness values in meat.

The pH values measured immediately after slaughter ranged from 6.81 to 6.08, and at 24 h

Table 1. Effect of management system and sex on physico-chemical quality of *semimembranosus* (SM), *longissimus thoracis et lumborum* (LTL) and *triceps brachii* (TB) muscles and sensorial evaluation on TB muscle.

	Management system			Sex		
Item	E	IN	IA	Male	Female	SEM[1]
FBW (kg)	6.78	7.40	7.11	7.19	6.98	0.09
Age at slaughter (days)	33.87^{a}	33.76^{a}	38.37^{b}	35.09^{a}	46.18^{b}	1.09
Carcass weights						
Hot carcass wt (kg)	3.64^{b}	4.09^{a}	3.72^{b}	3.86	3.76	0.05
Cold carcass wt (kg)	3.47^{b}	3.92^{a}	3.59^{b}	3.72	3.59	0.05
SM muscle						
L* (lightness)	52.20	52.12	52.63	53.50	50.92	0.46
a* (redness)	8.79^{b}	7.14^{a}	9.04^{b}	8.16	8.54	0.27
b* (yellowness)	10.51^{a}	9.89^{a}	7.90^{b}	10.45	8.27	0.30
LTL muscle						
L*	53.81	54.33	53.07	54.05	53.38	0.52
a*	11.20^{b}	8.28^{a}	6.56^{a}	9.06	8.32	0.37
b*	15.59	12.34	8.31	13.20	10.88	0.44
TB muscle						
L*	47.84	50.52	48.58	48.85	49.10	0.54
a*	9.45	10.26	10.18	10.14	9.75	0.26
b*	7.14	7.91	6.42	7.36	6.92	0.27
pH muscle SM						
0 hours	6.64	6.76	6.08	6.50	6.49	0.02
24 hours	5.80	5.68	5.72	5.72	5.75	0.04
pH muscle LTL						
0 hours	6.56	6.81	6.34	6.54	6.60	0.02
24 hours	5.75	5.70	5.82	5.70	5.81	0.03
pH muscle TB						
0 hours	6.36	6.54	6.42	6.48	6.40	0.03
24 hours	5.83	5.63	5.70	5.73	5.71	0.03
SM muscle						
Warner-Bratzler shear force (kg/cm^2)	3.17^{b}	5.37^{a}	2.72^{b}	3.15	4.44	0.18
Water holding capacity (%)	13.51^{a}	13.14^{a}	15.50^{b}	13.86	14.25	0.39
Cooking losses (%)	29.27^{a}	30.22^{a}	48.73^{b}	35.88	36.07	0.52
LTL muscle						
Moisture (%)	75.74	74.82	75.76	75.33	75.51	0.16
Protein (%)	21.43	22.17	21.59	21.76	21.69	0.63
Collagen (mg/g of dry matter)	1.03	1.08	1.03	1.05	1.04	0.01
Soluble collagen (mg/g of dry) Matter	1.02	1.02	1.02	1.03	1.01	0.00
Soluble collagen (%)	97.23	93.68	96.56	95.41	96.30	0.73
Fat (%)	1.73	1.97	1.55	1.79	1.70	0.09
Sensorial evaluation on TB muscle[2]	3.71	3.50	3.45	3.55	3.57	0.10

[a,b]Means with different superscripts differ significantly ($P < 0.05$).
[1]SEM = standard error of the mean.
[2]Panelists evaluated samples using a five-point descriptive scale for taste (1 = very bad, 2 = bad, 3 = regular, 4 = good, 5 = very good) according to UNE 87-005-92.

post-slaughter the values ranged from 5.83 to 5.63 (Table 1), which is in agreement with findings by others examining dairy goat kids (Argüello et al. 2005). In our study, the management system type had no effect on meat pH values (Table 1). These results are in agreement with the observations of Kirton et al. (1989) in lambs. In contrast, Solomon et al. (1986) reported a difference in pH in animals with greater glycogen concentrations that were fed high-energy diets. Carrasco et al. (2009) did not report pH differences between grazing and non-grazing lambs. Our results correspond to a normal range ruling out dark-cutting or stress problems, and that might be caused because transport and slaughtering processes were not stressful enough to modify the meat pH in any of the management systems.

The IN meat had the highest WBSF values, and no significant differences were observed between E and IA meat (Table 1). The E and IA meat apparently had less collagen and greater collagen solubility (i.e. characteristics of tender meat) compared with IN meat, although these apparent differences were not statistically significant. Carrasco et al. (2009) reported that effects of the diet on meat toughness are unclear, and thus results from different studies are contradictory. Some authors have reported greater values for shear force and toughness of meat from concentrate-fed lambs than from pasture animals (Santos-Silva et al. 2002), whereas others did not find significant differences (Notter et al. 1991). The results reported for E animals may be related to the relatively greater amount of exercise by kids from E, as suggested by Aalhus et al. (1991) for lambs, who found that muscles from exercised lambs were significantly tenderer than muscles from their indoor counterparts.

The IA kids' meat displayed the lowest capacity to retain water inside the muscle (Table 1). Lower pH values at 24 h and protein muscle percentages have been reported to be related in dry meats, but no differences in pH or muscle protein were observed in the present study. Carrasco et al. (2009) observed that cooking losses were not affected when lambs were fed in pastures rather than receiving commercial feed. Some researchers have compared different diets and observed no differences in cooking losses (Lanza et al. 2001), whereas others reported greater cooking losses for grazing animals (Santos-Silva et al. 2002). Kemp et al. (1976) suggested that cooking losses are mostly due to differences in fatness, but fattier muscles were observed to have lower cooking losses.

The type of management system did not affect meat composition, and results were closer to the often-quoted standard composition of normal adult mammalian muscle (Lawrie 1998), which is 75% water, 19% protein, 2.5% fat and 0.65% minerals. Argüello et al. (2005) reported no differences in meat composition due to diet (goat milk versus milk replacer) in dairy bred goat kids with a similar fasted BW (FBW).

Sensorial evaluation was not affected by the type of management system (Table 1). Similarly, Walshe et al. (2006) reported no sensorial differences between organically and conventionally reared steers.

Sex did not affect meat quality traits in the current study (Table 1), as similarly reported by Todaro et al. (2004) for Nebrodi kids. Although there were no statistical differences in WBSF due to sex, Hogg et al. (1992) and Johnson et al. (1995) found that WBSF values for female goats were significantly lower than castrated or intact male goats. The low fasted body weight (FBW) observed in the current study (Table 1) may have prevented significant differences between the sexes. Sex did not affect sensorial evaluation.

Fatty acid profile in intramuscular (TB muscle), subcutaneous, and intermuscular fat deposits are shown in Tables 2–4, respectively. The saturated fatty acids (SFA) percentages ranged from 45.23% to 63.91%, which are consistent with those reported by Bañón et al. (2006) and García-Navarro et al. (2008) in goats, and were mainly contributed by C14:0, C16:0 and C18:0. SFA percentage is studied because it increases the concentration of blood cholesterol, although the different SFA have different effects on cholesterol concentration. For example, lauric (C12:0), myristic (C14:0) and palmitic (C16:0) fatty acids raise the plasma cholesterol level (Denke and Grundy 1992; Derr et al. 1993; Sundram et al. 1994), whereas, stearic acid (C18:0) does not appear to have such an effect and is considered 'neutral' (Denke and Grundy 1992; Derr et al. 1993). While it is clear that C14:0 and C16:0 are responsible for increasing the total plasma and LDL (low density lipoprotein) cholesterol concentration, the other major SFA, i.e. C18:0, is not hypercholesterolaemic and does not increase the total cholesterol or LDL cholesterol concentration (Williams 2000). High dietary levels of long-chain SFA increase plasma cholesterol level compared with high levels of monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA; Grundy and Denke 1990).

Carcass weights and management system did affect significantly the SFA percentages in TB muscle, subcutaneous and intermuscular shoulder fat (Tables 2–4). Cifuni et al. (2000) found that the C16:0 percentage increased as carcass weight increased but C15:0, C14:0 and C24:0 percentages were not influenced. In the TB muscle, E had the lowest C14:0 percentages and the highest C16:0 percentages, and IN and IA showed similar percentages. In subcutaneous and intermuscular shoulder fat (Tables 3 and 4), the lowest C18:0 percentages were found in the IN samples, and those values were in agreement with a previous report (García-Navarro et al. 2008), but in the intermuscular shoulder fat samples, the highest C12:0 and C13:0 percentages were found in the IN samples. The C14:0 intramuscular percentage was the lowest in organic extensive meat. Although average percentages of C14:0 in TB muscle were lower than in sheep and beef (Banskalieva et al. 2000), the average percentages of C16:0 and C18:0 in the same muscle were similar. In rabbits, Hougham and Cramer (1980) demonstrated that muscle lipids in animals with high-activity metabolic profiles have larger amounts of 18-carbon fatty acids at the expense of 14- and 16-carbon fatty acids. This could explain the lower myristic fatty acid intramuscular percentage observed in organic extensive animals. In the current study, 18-carbon fatty acids (mainly oleic acid) were elevated at the expense of myristic fatty acid.

The MUFA percentages (Tables 2–4) were mainly due to oleic acid (C18:1), which is considered hypolipidaemic as it reduces cholesterol in plasma and triglycerides (Lee et al. 1998). The C18:1 concentration (mainly determining total MUFA) in goats is similar to that in other species, but the mean concentration of C16:1 in goat muscles is higher compared with lambs (Banskalieva et al. 2000).

The type of management system did not affect the percentage of C18:1 in subcutaneous or intermuscular deposits (Tables 3 and 4). In contrast, this percentage was greater in the TB muscle samples from the E carcasses (Table 2). As reported previously, the relatively high muscular activity of E animals causes a reduction in C14:0 content with a concomitant rise in the abundance of 18 carbon fatty acids (Hougham and Cramer 1980). Angood et al. (2008) did not observe that any management system affects the relative abundance of C18:1 in lambs. The lambs in that study were older than the kids in our current study, which may explain the contrasting results observed in the two studies. It has been reported that increasing age of slaughter of weaned kids receiving a concentrate-based diet decreases the MUFA level in subcutaneous adipose tissues (Bas et al. 1987). Bas et al. (1982) pointed out those levels of branched chain fatty acids (saturated C14, C15 and C16) in subcutaneous fat were higher in intact than castrated kids. In our study, sex did not have an effect on MUFA percentages and it was probably due to the fact that the animals were slaughtered too young.

As reported by Banskalieva et al. (2000), PUFA percentages were mainly due to linoleic (C18:2), linoleic (C18:3) and arachidonic (C20:4) fatty acid

Table 2. Effect of management system and sex on fatty acid composition (% of total fatty acids) of *triceps brachii* muscle intramuscular fat.

	Management system			Sex		
Fatty acid composition (%)	E	IN	IA	Male	Female	SEM[1]
C6:0	0.01	0.15	0.02	0.01	0.12	0.05
C8:0	0.87	0.48	1.90	0.22[a]	1.93[b]	0.35
C10:0	0.07	0.37	0.43	0.15	0.41	0.13
C11:0	ND	ND[2]	0.02	0.01	ND	0.00
C12:0	0.36	0.83	1.67	1.12	0.55	0.30
C13:0	5.52	3.92	4.74	5.00	4.46	0.42
C14:0	12.31[b]	19.27[a]	21.29[a]	17.53	16.48	1.37
C14:1	0.03	0.01	0.61	0.27	0.05	0.12
C15:0	0.29[ab]	0.06[b]	0.63[a]	0.21	0.39	0.08
C15:1	0.06[a]	ND	0.17[b]	0.05	0.09	0.02
C16:0	25.31[a]	23.02[ab]	21.27[b]	24.01	22.82	0.64
C16:1	0.43	0.27	0.63	0.31	0.56	0.09
C16:2	1.09	0.99	0.60	0.95	0.91	0.11
C16:3	0.36[b]	0.09[a]	0.23[ab]	0.21	0.26	0.03
C16:4	0.06	ND	0.10	0.03	0.08	0.01
C17:1	0.14[a]	0.02[a]	1.38[b]	0.04	0.87	0.22
C18:0	12.81	13.26	11.51	12.34	13.00	0.51
C18:1	36.66[b]	29.85[a]	28.35[a]	32.87	31.25	1.24
C18:2	1.61[b]	4.93[a]	2.29[b]	3.13	2.67	0.63
C18:3	0.10[ab]	0.01[a]	0.27[b]	0.07	0.16	0.03
C18:4	0.03	0.02	0.05	0.01	0.06	0.01
C20:0	0.23	0.05	0.09	0.17	0.08	0.05
C20:1	0.04	0.04	0.1	0.02	0.09	0.01
C20:3	ND	ND	0.01	0.00	ND	0.00
C20:4	0.57	0.79	0.83	0.50	0.98	0.20
C20:5	0.03	ND	0.12	0.04	0.04	0.02
C22:0	0.01	0.07	0.00	0.03	0.03	0.01
C22:2	0.18	0.24	0.30	0.16	0.32	0.06
C23:0	0.73	1.15	0.21	0.42	1.15	0.23
C24:0	0.01[b]	0.38[a]	0.12[ab]	0.13	0.22	0.05
C24:4	0.10	ND	0.00	0.07	ND	0.03
C26:6	0.00	ND	0.05	0.03	ND	0.01
All SFA	58.52	63.01	63.91	61.34	61.63	1.11
All MUFA	37.36[b]	30.19[a]	31.23[a]	33.57	32.90	1.13
All PUFA	4.12	6.81	4.86	5.08	5.47	0.73
Atherogenicity index[3]	1.81[b]	2.73[a]	3.00[a]	2.46	2.32	0.25

[a,b]Means with different superscripts differ significantly ($P < 0.05$).
[1]SEM = standard error of the mean.
[2]ND = not detected.
[3]Atherogenicity index = (C12:0 + (4 × C14:0) + C16:0)/(MUFA + PUFA), Ulbricht and Southgate (1991).

Table 3. Effect of management system and sex on the fatty acid composition (% of total fatty acids) of subcutaneous shoulder fat.

	Management system			Sex		
Fatty acid composition (%)	E	IN	IA	Male	Female	SEM[1]
C6:0	0.00	0.00	0.04	0.00	0.03	0.01
C8:0	0.27	0.08	0.07	0.16	0.11	0.07
C10:0	0.16	0.27	0.24	0.12	0.32	0.07
C11:0	0.00	0.00	0.07	0.00	0.05	0.02
C12:0	0.61	1.59	1.40	1.15	1.23	0.36
C13:0	1.26	1.44	0.71	1.43	0.80	0.16
C14:0	8.98	9.51	8.65	9.23	8.78	0.51
C14:1	0.15	0.06	0.17	0.09	0.17	0.02
C15:0	0.69	0.07	0.61	0.57	0.43	0.12
C15:1	0.17^{ab}	0.01^{a}	0.28^{b}	0.12	0.22	0.04
C16:0	28.27	29.37	28.75	29.14	28.42	0.83
C16:1	1.00	0.66	1.07	1.05	0.84	0.16
C16:2	0.95	0.65	0.76	0.61	0.96	0.16
C16:3	0.62^{b}	0.14^{a}	0.46^{b}	0.40	0.45	0.05
C16:4	0.22^{b}	0.02^{a}	0.03^{a}	0.10	0.08	0.03
C17:1	0.12^{a}	0.03^{a}	0.37^{b}	0.11	0.27	0.05
C18:0	14.66^{b}	9.22^{a}	14.05^{b}	12.67	13.22	0.64
C18:1	40.43	44.77	40.81	41.36	42.08	0.96
C18:2	1.36	2.09	1.05	1.37	1.49	0.19
C18:3	0.00	ND[2]	0.02	ND	0.01	0.01
C18:4	ND	0.00	0.07	0.04	0.02	0.01
C20:1	0.01	0.02	0.01	0.01	0.02	0.01
C22:2	0.01	ND	0.29	0.25	0.01	0.10
C23:0	0.03	0.00	0.00	0.02	0.01	0.01
C24:0	0.01	0.00	0.00	0.00	0.00	0.00
All SFA	54.94	51.55	54.58	54.48	53.38	0.98
All MUFA	41.89	45.55	42.72	42.75	43.59	0.94
All PUFA	3.17	2.90	2.69	2.77	3.02	0.17
Atherogenicity index[3]	1.44	1.42	1.43	1.48	1.39	0.21

[a,b]Means with different superscripts differ significantly ($P < 0.05$).
[1]SEM = standard error of the mean.
[2]ND = not detected.
[3]Atherogenicity index = (C12:0 + (4 × C14:0) + C16:0)/(MUFA + PUFA), Ulbricht and Southgate (1991).

(Tables 2–4). The percentage of C18:2 in intermuscular and intramuscular depots (Tables 2 and 3) in carcasses from IN and IA management systems, which were the heaviest, was significantly greater than in carcasses from the E. A similar trend was observed in subcutaneous deposits (Table 4), although the difference was not statistically significant. Banskalieva et al. (2000) found that the content of the level of MUFA in all deposits decreased with increasing live weight. The feedstuff for the IN dams was prepared with sunflower meal, and Eknaes et al. (2009) recently demonstrated that the inclusion of sunflower in goat feed increases the C18:2 in milk. This increase may have resulted in the observed increase in this acid in IN fat deposits. In addition, the diet for E dams did not include any sunflower, and the percentage of C18:2 in intensive milk replacer were very low (approximately 3%, data provided by manufacturer). It is well established that docosanoic acid and eicosapentaenoic acid (EPA) are beneficial to human health (Horrocks and Yeo 1999), but meat and meat products generally do not contain substantial levels of these fatty acids. Fortunately, goat meat from the IA showed high levels of the mentioned fatty acids. The highest concentration of long chain n-3 PUFA was found in the TB samples from the IA. In fact, the consumption of goat meat from IA with increased n-3 fatty acid concentration can contribute to human requirements for these fatty acids, especially alpha linoleic acid (C18:3n-3), EPA (eicosapentaenoic acid), DPA (docosapentaenoic acid) and DHA (docosahexanoic acid). Meat, milk and eggs are the only sources of long chain n-3 PUFA in the diet of people who do not consume fish. Long chain n-3 PUFA like EPA and DHA play an important role in the development of cerebral and retinal tissues and in the prevention of heart diseases and some cancers (Simopoulos 2002).

The results reported in Tables 2–4 support the notion that DHA and EPA are indeed present in goat

Table 4. Effect of management system and sex on fatty acid composition (% of total fatty acids) of intermuscular shoulder fat.

	Management system			Sex		
Fatty acid composition (%)	E	IN	IA	Male	Female	SEM[1]
C8:0	ND[2]	0.14	0.11	0.06	0.09	0.05
C10:0	0.08	0.20	0.20	0.12	0.19	0.06
C12:0	0.14^{b}	1.43^{a}	0.50^{ab}	0.60	0.55	0.19
C13:0	0.35^{b}	1.99^{a}	1.06^{ab}	0.81	1.18	0.23
C14:0	5.55	5.72	6.65	4.77	7.17	0.89
C14:1	4.33	4.28	4.02	4.80	3.65	1.08
C15:0	0.29	0.20	0.92	0.15	0.88	0.22
C15:1	0.07	1.88	0.16	0.04	0.89	0.39
C16:0	33.44	30.11	31.29	31.66	31.93	1.15
C16:1	0.76	0.97	1.05	0.78	1.06	0.18
C16:2	0.73	0.42	0.88	0.68	0.77	0.16
C16:3	0.32	0.16	0.42	0.17	0.47	0.06
C16:4	ND	ND	0.01	ND	0.01	0.00
C17:1	0.17	0.06	0.17	0.11	0.18	0.04
C18:0	10.78^{b}	5.33^{a}	10.41^{b}	8.98	9.87	0.97
C18:1	41.93	44.48	41.00	43.36	38.36	0.99
C18:2	0.61^{b}	2.44^{a}	0.70^{b}	0.83	1.24	0.25
C18:3	ND	0.01	0.04	0.02	0.02	0.00
C18:4	ND	0.03	0.03	0.00	0.04	0.01
C20:0	ND	0.08	0.14	0.12	0.04	0.03
C20:1	ND	0.02	0.05	0.04	0.01	0.01
C20:4	ND	0.00	0.01	0.01	0.00	0.00
C22:2	0.01	0.02	0.13	0.04	0.08	0.03
C23:0	ND	0.01	0.01	0.01	0.01	0.01
C26:6	ND	0.00	0.01	0.00	0.00	0.00
All SFA	52.60	45.23	51.32	47.28	53.24	1.71
All MUFA	45.73	51.69	46.46	51.00	44.13	1.80
All PUFA	1.67	3.08	2.22	1.72	2.63	0.29
Atherogenicity index[3]	1.17	0.99	1.19	0.97	1.30	0.23

^{a,b}Means with different superscripts differ significantly ($P < 0.05$).
[1]SEM = standard error of the mean.
[2]ND = not detected.
[3]Atherogenicity index = (C12:0 + (4 × C14:0) + C16:0)/(MUFA + PUFA), Ulbricht and Southgate (1991).

kid meat, suggesting that the consumption of this meat may have health benefits in a general sense.

Sex did not affect the SFA, MFA or PUFA percentages in any fat depot (Tables 2–4), but it must be said that sex differences in fatty acid composition in the literature have been inconsistent. For example, Banskalieva et al. (2000) reported that female goats had lower levels of C14:0 and C18:0, and that was similar to results for heifers and steers of Marchello et al. (1967) and Waldman et al. (1968). Opposite results have been reported by Malau-Aduli et al. (1998) with heifers and steers.

The atherogenicity index (Ulbricht and Southgate 1991) values in subcutaneous and intermuscular fat deposits (Tables 3 and 4) were not affected by the type of management system. In contrast, the intramuscular fat deposit (Table 2) was affected by the type of management system, with E samples showing the lowest atherogenicity index. The reason for these differences is probably the low C14:0 percentage and high C18:0 percentage in the E muscle fat deposit because both percentages are modulated by grazing-related muscular activity. Fehily et al. (1994) reported that an increase of 0.2 in the atherogenicity index is associated with an increase in plasma cholesterol of 1.93 mg/dL in consumers. Although further should be performed, the consumption of E kid meat may have greater health benefits compared with consumption of conventional kid meat. The sex did not affect the atherogenicity index of any fat depot.

4. Conclusions

Extensive system produces goat kid meat that is similar to meat produced by intensive with natural and artificial rearing system with respect to physical characteristics and the proximal chemical composition. However, fatty acid composition is influenced by the managements system, with the meat from the extensive system the one with the highest oleic fatty acid content and lowest saturated fatty acids content, as well as the lowest atherogenicity index. Although further studies are required, our results suggest that meat from extensive system is truly unique and could provide more health benefits than meat from intensive with natural and artificial rearing systems.

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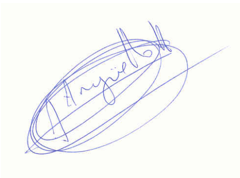
Dear Dr

I inform you that your manuscript entitled "**Effects of three management systems on meat quality of dairy breed goat kids**" with authors PEDRO ZURITA-HERRERA; JUAN VICENTE DELGADO BERMEJO; MARIA ESPERANZA CAMACHO; ROBERTO GERMANO COSTA, has been accepted in our journal.

Yours sincerely



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Multivariate analysis of meat production traits in Murciano-Granadina goat kids

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ABSTRACT

Growth, carcass quality, and meat quality data from Murciano-Granadina kids (n = 61) raised under three different systems were collected. Canonical discriminatory analysis and cluster analysis of the entire meat production process and its stages were performed using the rearing systems as grouping criteria. All comparisons resulted in significant differences and indicated the existence of three products with different quality characteristics as a result of the three rearing systems. Differences among groups were greater when comparing carcass and meat qualities as compared with growth differences. The paired analyses of canonical correlations among groups of variables integrated in growth, carcass and meat quality, resulted in all being statistically significant, pointing out the canonical correlation coefficient between carcass quality and meat quality.

1. Introduction

Meat production is completed in three different stages. The first stage is rearing, and its focus is on growth parameters. The second, slaughtering, is determined by the carcass characteristics, which includes the proportion of the most valuable pieces and the tissue contents. The third stage is commercialization, which is defined by meat quality, and includes traits related to sensorial perception. The quality of the final product, the meat, is determined not only by the sum of the isolated effects of every studied trait within each stage of production (i.e. slaughter and commercialization) but also by the relationships among these traits and how groups of traits interact within each stage (and across multiple stages). Canonical discriminant analysis has been used to classify animals based on some meat quality parameters in lamb (Juárez et al., 2008), but no such studies have been carried out in goats.

Although the Murciano-Granadina dairy goat breed is the most widespread Spanish goat breed (found in Mediterranean and Latin American countries and Western Africa), the effects of the new Agricultural Common Policy from the European Union and the international globalization of the economy are compromising the profitability of dairy goat farms along with other rural activities. Undoubtedly, one way to increase profits is to define specific goat meat products that are a component of local traditions and protect them with commercial designations, such as a Geographically Protected Indication (Dubeuf, Morand-Fehr, & Rubino, 2004).

Here we developed a broad study of the meat production process of Murciano-Granadina kids using variables associated with the three production stages. Our analysis consisted of a deep multivariate analysis and used advanced methods such as canonical discriminant analysis, cluster analysis, and canonical correlation analysis (Everitt & Dunn, 1991), which are not commonly used in complex meat production studies involving variables that affect such different aspects of the meat production process. It would allow us to distinguish among goat meat products of different rearing systems while taking into account the whole production process and its integrated stages. As a result, this study could be a model for meat production characterization involving the entire production process in goats as well as in other species.

2. Materials and methods

2.1. Animals and management treatments

Murciano-Granadina kids (n = 61; 28 females and 33 males) were randomly chosen from several farms and were reared under three different management systems (organic extensive, intensive with natural rearing, and intensive with artificial rearing) in the experimental center of the Murciano-Granadina breeders association (Albolote, Granada). Animal handling was carried out according to the guidelines of the EC Directive 86/609/EEC (European Communities, 1986).

The organic extensive system involved 21 kids (9 females and 12 males) suckled directly from dams and raised on a free-range pasture containing mostly wheat *(Triticum sativum Lam., T. vulgare)*, oat

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(Avena sativa), and chickpeas (*Cicer arietinum*), with no additional feedstuff. At night, they were housed with their mothers in a stable. The intensive with natural rearing system involved 9 females and 11 males suckled directly from dams; they had access to alfalfa hay and cereal straw. The intensive natural rearing kids did not have access to a pasture. The intensive with artificial rearing system involved 10 females and 10 males. Goat kids were separated from dams after birth, housed in a nursing parlor, and fed colostrum for the first 2 days, as described by Castro, Capote, Álvarez, and Argüello (2005). Then, kids had free access to milk replacer 24 h a day (Univet lambs and kids 60; Nutral S.A., Madrid, Spain; 6.00% ash, 0.04% cellulose, 24.00% protein, and 24.50% fat, on dry matter) that was distributed by a nursing device. This feeding regimen was supplemented with alfalfa hay. Kids from all three systems had free access to water at all times.

2.2. Growth traits

Kids were weighed at birth and then weekly until slaughter using a digital hook weight (PCE-HS 50, maximum = 50 kg, error = 20 g; PCE Group Ibérica, Albacete, Spain). Estimated weights (EW) were as described by Telo Da Gama (2002).

2.3. Carcass traits

Kids were slaughtered when their body weight was 7 ± 1 kg. Kids were fasted with free access to water during the 24 h before slaughter and were slaughtered using captive bolt stunning followed by throat cut to sever carotid arteries and jugular veins. Kids were dressed according to Colomer-Rocher, Morand-Fehr, and Kirton (1987). Weights of the blood, skin, fore and hind feet, head, full gastrointestinal track, liver, bladder, testicles, spleen, right kidney, lungs and trachea, heart, and thymus were recorded using electronic scales (G-310, Dibal S.A., Bilbao, Spain; Tefal model Gourmet, Groupe SEB Ibérica, Barcelona, Spain). The hot carcass weight was determined (PCE-HS 50), and after carcasses were chilled for 24 h at 4 °C, the chilled carcass weight was recorded. Empty body weight (EBW) was calculated by subtracting the weight of the gastrointestinal contents from the fasted body weight (FBW). Dressing carcass percentages were calculated using the chilled carcass weight (CCW), hot carcass weight (HCW), FBW, and EBW. The commercial and real dressing percentages (CDP and RDP, respectively) were calculated as follows:

$$CDP = 100 \times (CCW / FBW)$$
$$RDP = 100 \times (HCW / EBW)$$

Carcass measurements included leg length (from the symphysis pubis to the tarsal–metatarsal joint), carcass length (from the symphysis pubis to the anterior edge of the middle of the first rib), rump width, and breast depth (the maximum distance between the sternum and the sixth thoracic vertebra).

2.4. Primal cut and tissue composition measures

After chilling, carcasses were split. The left side was divided into five primal cuts (neck, flank, ribs, shoulder, and long leg) and three minor cuts (kidney, kidney fat, and tail), as described by Colomer-Rocher et al. (1987). Primal cuts were weighed (Tefal model Gourmet) and dissected into separable tissues (subcutaneous and intermuscular fat, lean, and bone). The separable tissues were weighed as described above, and fat samples were frozen.

2.5. Meat quality attributes

Meat quality measurements were made on the right side of each carcass. Muscle pH was determined using a Crison 166 pH meter with a combined electrode (Crison Instruments S.A., Barcelona, Spain) by inserting the probe into the *longissimus* (at the 12/13th rib site), *semimembranosus* (central portion), and *triceps brachii* (central portion) muscles, immediately after slaughter and 24 h post mortem. Muscle color was measured on the surface of those muscles immediately after slaughter using a Minolta CR200 Chroma-meter (Konica Minolta Sensing, Inc., Osaka, Japan) in the CIE L*a*b* color space using a D65 Iluminant (CIE, 1986), in which L* indicates relative lightness, a* indicates relative redness, and b* represents relative yellowness. Two determinations per sample were done.

M. semimembranosus, *M. longissimus*, and *M. triceps brachii* samples 5 cm long were excised 24 h after slaughter, sealed in vacuum bags, and stored at −18 °C until laboratory determinations could be conducted, as was done with subcutaneous and intermuscular shoulder fat.

The meat water-holding capacity was measured according to Grau and Hamm (1953) using *M. semimembranosus* samples that were cooked in plastic bags in a water bath at 75 °C for 45 min to determine cooking losses. Cooked muscle cores (1 × 1 cm and ≥ 3 cm long) were cut parallel to the muscle fibers, and shear force values were recorded using an Instron Universal Testing Machine (Instron, model 4465, Instron Co., Canton, Massachusetts, USA) with a Warner-Bratzler shear force device.

Proximate analysis was performed on *M. longissimus* according to AOAC (1984) procedures 24003, 13032, and 2057. The collagen content and solubility of *M. longissimus* samples were determined as described by Hill (1966).

Fatty-acid composition was determined according to Granados (2000). Fat was extracted from *M. triceps brachii*, and subcutaneous and intermuscular shoulder fat was collected as described by Folch, Lees, and Stanley (1957). Supelco® 37 Component FAME Mix (Sigma-Aldrich, St. Louis, Missouri, USA) was used as the external standard, and C21:0 was used as the internal standard. Briefly, fatty acids were separated before derivatization (ISO Norm 5509, 2000) in a gas chromatograph (Model HP 5890 Series II GC; Hewlett–Packard, Avondale, PA) equipped with a flame ionization detector and a phenyl-methyl-siloxane (cross-linked at 5%) capillary column (30 m long, internal diameter of 0.25 mm, film thickness of 0.25 μm). The detector and the injector were maintained at 280 °C. The carried gas was helium at a flow rate of 1 ml/min and a division ratio of 100:1.

2.6. Sensory panel evaluation

Samples of *M. triceps brachii* were cooked in plastic bags in a water bath at 75 °C for 45 min. A ten-member semi-trained panel evaluated samples using a five-point descriptive scale for taste (1 = very bad, 2 = bad, 3 = regular, 4 = good, 5 = very good) according to UNE 87-005-92 (AENOR, 1992). Assessments were performed in a controlled sensory analysis laboratory with individual booths. To avoid the influence of a carry-over effect, samples were served to panelists in a random order, and they were asked to eat a small (3 × 3 cm) piece of unsalted white bread and to rinse their palate with water before the evaluation and in between each evaluation sample (Hildrum, Nilsen, Bekken, & Naes, 2000). Each panelist evaluated six random samples of meat per session, with a total of two sessions per day.

2.7. Statistical analysis

2.7.1. Data editing and variables

Three animals with incomplete information in growth variables were removed from the statistical analysis. Also removed were variables with excessive missing data (this was the case, for example, of the fatty acid analysis) or overly strong correlations with other variables (to avoid redundancies), variables excluded were not pointed out in Table 1.

Table 1 shows the final result of the data editing and also the list of variables included in the analysis ordered by stage of the production process. Based on the number of animals distributed by sex and

Table 1
List of variables included in the analysis after data editing, ordered by stage of the production process and their descriptive statistics.

Variable	Management system		
	Intensive natural rearing	Organic extensive	Intensive artificial rearing
Growth stage			
EW[1] at birth, kg	3.22[a]	2.85[b]	2.88[b]
EW at 7 days old, kg	3.91[a]	3.51[b]	3.33[b]
EW at 14 days old, kg	4.37[a]	4.25[ab]	3.95[b]
EW at 21 days old, kg	5.71[a]	5.08[b]	4.86[b]
EW at 28 days old, kg	6.96[a]	6.23[b]	5.89[b]
FBW, kg	7.40	6.78	7.11
Carcass quality variables			
Blood weight, g	289.50	500.00	258.85
Skin weight, g	630.75[a]	574.00[a]	659.85[b]
Fore and hind feet weight, g	315.35	284.48	337.95
Head weight, g	535.85	504.43	557.40
Full gastrointestinal track weight, g	969.55	911.00	1040.60
Liver weight, g	182.65	156.76	194.15
Bladder weight, g	14.25	15.37	17.89
Testicles weight, g	11.82	23.75	17.50
Spleen weight, g	19.40	18.81	16.90
Right kidney weight, g	37.05	35.62	34.90
Lungs and trachea weight, g	150.45	168.57	165.95
Heart weight, g	54.95	45.76	45.90
Thymus weight, g	13.84	16.33	19.84
Leg length, cm	23.91[a]	25.75[b]	23.85[a]
Carcass length, cm	38.96[a]	41.01[b]	40.59[b]
Rump width, cm	9.44[a]	9.24[a]	8.87[b]
Breast depth, cm	14.94	15.21	14.96
Hot carcass weight, kg	4.09[a]	3.64[b]	3.72[b]
Chilled carcass weight, kg	3.92[a]	3.47[b]	3.59[b]
Shoulder weight, g	330.60[a]	315.71[b]	311.95[ab]
Long leg weight, g	449.65	407.95	421.80
Ribs weight, g	653.40[a]	510.19[b]	554.65[c]
Neck weight, g	123.40	117.57	121.35
Flank weight, g	134.30[a]	136.29[a]	124.70[b]
Meat quality variables			
M. longissimus L* value	52.12	52.20	52.63
M. longissimus a* value	7.14[a]	8.79[b]	9.04[b]
M. longissimus b* value	9.89[a]	10.51[a]	7.90[b]
M. semimembranosus L* value	54.33	53.81	53.07
M. semimembranosus a* value	8.28[a]	11.20[b]	6.56[a]
M. semimembranosus b* value	12.34	15.59	8.31
M. triceps brachii L* value	50.52	47.84	48.58
M. triceps brachii a* value	10.26	9.45	10.18
M. triceps brachii b* value	7.91	7.14	6.42
M. semimembranosus water-holding capacity, %	13.14[a]	13.51[a]	15.50[b]
M. semimembranosus Warner-Bratzler shear force, g/cm[2]	5.37[a]	3.17[b]	2.72[b]
M. semimembranosus cooking loss, %	30.22[a]	29.27[a]	48.73[b]
M. longissimus collagen, mg/g dry matter	1.08	1.03	1.03
M. longissimus protein, %	22.17	21.43	21.59
M. longissimus moisture, %	74.82	75.74	75.76
M. longissimus fat, %	1.97	1.73	1.55
Sensory evaluation on *M. triceps brachii* [1]	3.50	3.71	3.45

Within a row, means without common letters differed significantly ($P<0.05$).
[1] EW: estimated weight.
[2] Panelists evaluated samples using a five-point descriptive scale for taste (1 = very bad, 2 = bad, 3 = regular, 4 = good, 5 = very good) according to UNE 87-005-92.

management system (see Section 2.1), this is a large enough sample size for the multivariate analysis.

2.7.2. Multivariate analysis

The multivariate analysis was designed based on the two questions of interest. (1) Do these three management systems produce meat that represents a single product, or does each system produce a distinct product? (2) What relationships exist among the variables associated with each of the meat production stages?

The answer to the first question was resolved by two multivariate techniques. The first is the canonical discriminant analysis (Everitt & Dunn, 1991; Tabachnick & Fidell, 1996), which gave us information about the differences or similarities of the products obtained from each of the management systems step by step (growth, carcass quality, and meat quality) and globally. The second involves clustering based on the Euclidian distances among groups calculated with individual Mahalanobis distances (Everitt & Dunn, 1991; Tabachnick & Fidell, 1996). This analysis gave us information regarding not only the differences among products but also the relationships among the variables of the production stages.

The second question was answered by a canonical correlation analysis among groups of variables integrated within each of the meat production stages.

All statistical analyses were performed using the Statistical Analysis Software program, version 5 for Windows (1996, SAS Institute Inc., Cary, North Carolina, USA).

2.7.3. Characterization of the product: canonical discriminant analysis and clustering

The first step in the canonical discriminant analysis was to determine the a priori basis for grouping the management system. The analysis was developed separately for each of the production stages (growth, carcass quality, and meat quality) and for the whole group of variables.

The efficiency of the discriminative power of a given model was determined by the test of significance of the Wilks' lambda value. The capacity of prediction for each model was tested using the absolute assignment of individuals to the pre-assigned group. The distances among groups were determined using the Mahalanobis distances among groups and their statistical significance.

The canonical discriminant analysis resulted in a graphic representation of the location of the observations in the space formed by the first two grouping variables. It gave a visual confirmation of the existence of groups among the variables. Thus we generated similar graphic representations for the whole production process and its stages.

The second step in the characterization of the product was the study of the concrete relationships that exist among the discriminated groups. The cluster analysis was appropriate because it provides not only a simple representation of the groups but also a quantification of the relationships among these groups (Tabachnick & Fidell, 1996) and complements the discriminant analysis because the latter explores only associations between data without explaining why they exist.

In this research we have used the joining tree clustering method, which is based on a plot that shows linkage distances along the horizontal axis. Every node in the representation points out where a cluster is defined. When the data have a structure, with groups of similar elements, this grouping (structure) is established in the hierarchical tree in the form of different branches. Euclidian distances were used for the analysis.

Clustering analysis was carried out among the groups formed with individuals belonging to each management system. These analyses were developed using the individual Mahalanobis distances performed in the canonical discriminant analysis and were carried out for the whole production process and for each of its stages.

The results are provided as individual plots representing the determined clusters and their linkage points.

2.7.4. Relationships among groups of variables inside the production process: canonical correlations

This is a multivariate statistical model to study the interrelationships among groups of multiple dependent variables and multiple independent variables. Variables were grouped according to the stage of the meat production process.

Among the objectives pointed out by Thompson (1984), we have extracted two that support the characterization of meat production in the Murciano-Granadina goat breed. The first determines the magnitude of the relationships that may exist between the groups of variables, and the second measures the relative contribution of each variable to the canonical functions (relationships).

We analyzed the canonical correlations by paired groups of variables: growth–carcass quality, carcass quality–meat quality, and growth–meat quality. Thus we obtained the values of the canonical correlations and their significance by means of chi-square tests with successive roots removed. Canonical coefficients of the determinations are also shown. As an indicator of the robustness of the canonical correlations, the calculated variance and the total redundancy are also shown for each set of variables.

3. Results and discussion

Canonical discriminant analysis provided results regarding the possibility of differentiating among different meat products within a single breed based on different management systems. Table 2 shows the general results obtained from the canonical discriminant analysis with all the variables measured in our meat production process and also with variables from the three stages (growth, carcass quality, and meat quality).

In all cases, discrimination among management systems was evident because the *F* statistics of the Wilks' lambda were always significant for the first discriminant variable. *P*-values indicated a lower capacity of discrimination for the variables involved in the growth stage because the on-farm period of the meat production process did not lead to important differences among the classification groups. In recent studies, such as Camacho et al. (2008), it was pointed out that the growth stage was not affected by the management system. Analyzing the variability among all the variables of the production process indicated that these three management systems could be easily differentiated. This outcome is supported by the Mahalanobis distances among groups (Table 1, Supplementary material) and in the classification matrix of each animal into its pre-assigned group (Table 2, Supplementary material), which shows that the distances among groups were very significant and all individuals were correctly assigned. This is more evident in the graphical representation of the results in two dimensions (Fig. 1). There were significant differences among groups when all variables of the production process were introduced into the model.

A cluster analysis supported these results, as the Euclidian distances obtained (Table 3, Supplementary material) led to clear divisions among the groups, which can easily be appreciated (Fig. 2). Clustering showed an association between the organic extensive system and the intensive with artificial rearing system as compared with the intensive with natural rearing system. The intensive with natural rearing system was the only one that produced stress because of the change of feeding in a concrete period which is the weaning. Organic extensive and intensive with artificial rearing systems minimized such stress because the kids experienced no sudden changes in feeding. This could explain the results, although after observing the magnitude of the linkage distancing, the meaning of these distances may only be minimally important.

Table 2
Results of the canonical discriminant analysis for the whole production process and its stages.

	Variables in the model	Groups	Wilks' lambda	*F*	*P*
Whole process	47	3	0.00001	$F(94,18)=53.28$	<0.001
Production stage					
Growth	6	3	0.56239	$F(12,100)=2.78$	<0.003
Carcass quality	24	3	0.00376	$F(48,70)=22.32$	<0.001
Meat quality	17	3	0.02310	$F(34,84)=13.78$	<0.001

These findings are very important, because they indicate that it would be necessary to define trademarks for each management system within a possible area of product protection such as a Geographically Protected Indication.

The three stages of production differed not only in their magnitude of discrimination but also in the relationships among the groups of variables. Whereas the growth stage resulted in the lowest, albeit significant, discrimination among groups, carcass quality had the highest discrimination power. This can be observed in Tables 1 and 2 (both in Supplementary material), where the magnitude and significance of the Mahalanobis distances and the correct assignment of animals to groups based on predictions support the preceding comments. The clustering of observations by management group differed, depending on the stage considered (Fig. 1). In the growth stage, it was difficult to separate the groups within the space created by the two axes, whereas these groups were well defined in the carcass quality and meat quality stages. In the carcass stage, the organic extensive group was clearly defined, whereas the other two maintained a certain degree of overlap. In the meat quality stage, the intensive artificial rearing group was the most well defined, but in this case the other two groups maintained a slight definition in the space as well. In any case, the discriminant results did not provide any direct information about which group produced better or worse products; they only pointed out the distinctions among groups, which we then interpreted according to other cultural criteria.

The interpretation of these patterns of discrimination is that the carcass was negatively affected by the extensive system and had characteristics (i.e. leg and carcass lengths) that were generally of lower quality; both of the intensive systems resulted in better carcasses according to generally accepted valuation. The effects on the meat quality stage were, however, just the opposite. Here the artificial rearing seemed to affect meat quality negatively in contrast with the meat obtained from the organic extensive (which had the best meat quality) and the intensive with natural rearing systems. Characteristics which affect meat quality negatively were *M. semimembranosus* water-holding capacity, *M. semimembranosus* Warner-Bratzler shear force and *M. semimembranosus* cooking loss.

Cluster analysis supports the results mentioned above. The magnitude of the linkage distances (Table 3, Supplementary material) and especially the graphical representations of Fig. 2 show the clusters formed in the three stages, which in general are in agreement with the results of the canonical discriminant analysis.

It is important to determine which variables involved in the analysis have the greatest effect on the quality of the final product, because this knowledge could simplify future evaluations of this product. This is additional information that could be extracted from the present study by determining the Wilks' lambda for the overall model that will result after certain variables are removed. Tables 4 and 5 (both in Supplementary material) show the results obtained when individual variables were analyzed for their effects on the model. We first carried out this analysis for the whole process involving all the variables of the experiment. Table 4 (Supplementary material) shows that the most discriminatory variables are estimated weight at 7 and 14 days of age and FBW for the growth stage. For the carcass quality stage, the most discriminatory variables are blood, head, heart, leg length, breast depth, hot carcass weight, and flank weight. For the meat quality stage, these variables are *M. longissimus* a^* and b^* values; *M. semimembranosus* Warner-Bratzler shear force; *M. semimembranosus* cooking loss; and *M. longissimus* collagen, moisture, and fat content.

The discriminatory variables were not strictly coincident with those obtained when the variables were studied independently for each stage (Table 5, Supplementary material). Estimated weight at

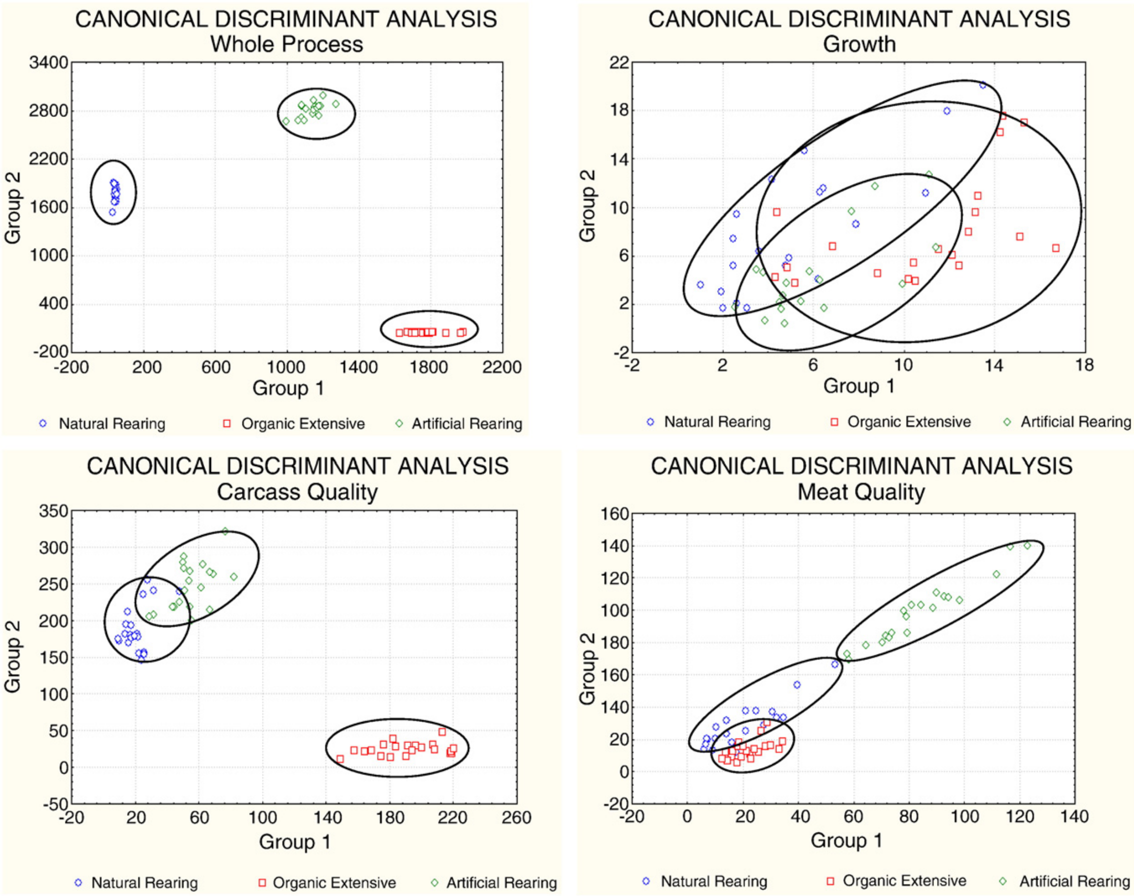

Fig. 1. Plot of the canonical discriminant analysis results for the whole production process and for the growth, carcass quality and meat quality stages of the production process, defined by axes formed with the first two canonical variables (Group 1 and Group 2, respectively).

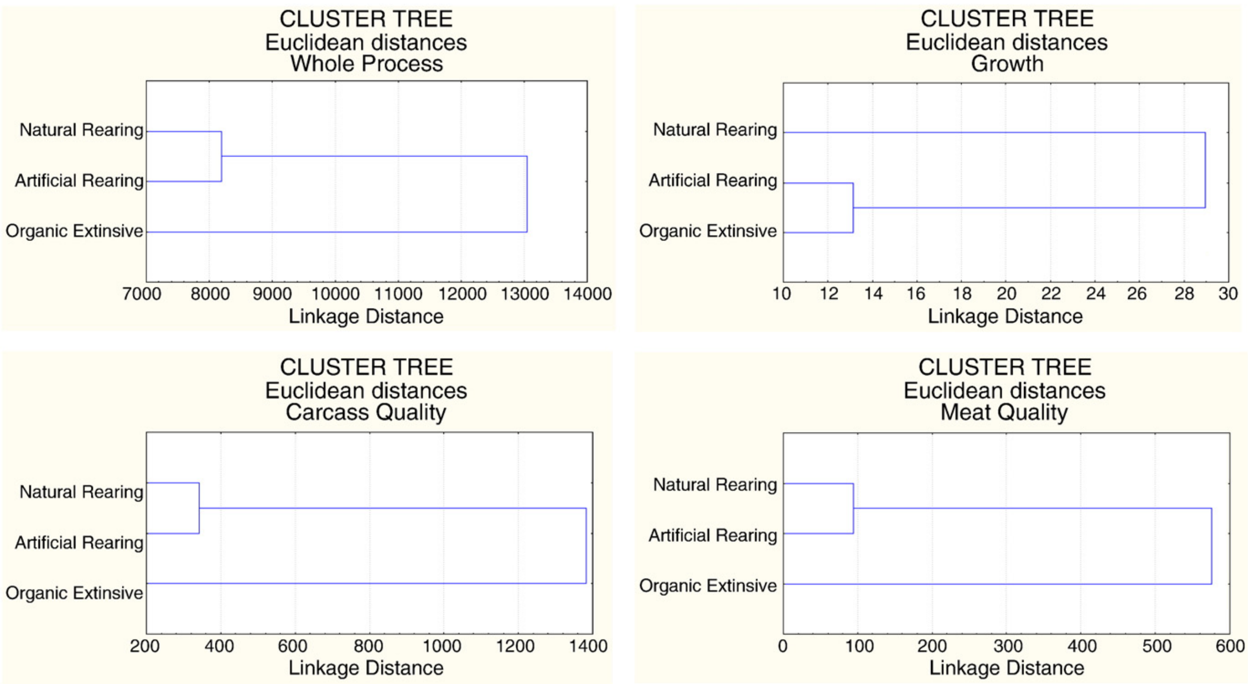

Fig. 2. Plot of the cluster analysis based on Euclidian Distances developed for the whole production process and for the growth, carcass quality and meat quality stages.

14 days old was the only variable that showed an intense power of discrimination for the growth stage; these were less robust results than the ones obtained for the whole process. In contrast are the results of the carcass quality stage, for which there were more variables that gave a strong power of discrimination; the same was found for the meat quality stage. These variations are common in canonical discriminant analysis because the variables are strongly related to the model; the inclusion of a new variable or the removal of another affects the final result (Everitt & Dunn, 1991; Tabachnick & Fidell, 1996). It is in fact the trends that are important, and they consistently supported the same conclusions, with the exception of the growth period, perhaps because that stage included fewer variables, more of which had a greater level of redundancy. We note here that although several papers using canonical discriminant multivariate methods in meat science have been recently published, we have not found another study that analyzed the discrimination produced by the effects of the management system on the final product while taking into account the whole production process and its integrated stages. This originality is more evident in studies of goats, a species that has been the subject of only a few meat science studies and that is rarely characterized by multivariate techniques. We note that although cluster analysis has been used in similar experimental designs, it has not been used to address the questions posed here.

The second main objective of this paper was the investigation of the relationships among the variables grouped according to the three stages of the meat production process (growth, carcass quality, and meat quality). We analyzed the general characteristics of the canonical correlation analysis between variables from the paired stages (growth–carcass quality, carcass quality–meat quality, and growth–meat quality; Table 3). We note that the variables associated with the growth stage were the most redundant, and thus we had the greatest difficulties when predicting their canonical coefficient of correlation. The paired analysis indicated that there were significant differences between the stages, with high coefficients of correlation (Table 6, Supplementary material) for the first roots for growth and meat quality, carcass quality and meat quality, and growth and carcass quality. When growth and meat quality were analyzed, there was sufficient evidence to confirm that the growth traits were strongly correlated with meat quality traits. Thus, predictions of the post-mortem characteristics can be made based on multiple regression models using weights at different ages as independent variables. The relationship between meat quality traits and carcass quality traits was very strong, and it was strong between growth and carcass quality traits.

A special consideration must be made concerning the lambda prime estimation, which is a modification of Wilks' lambda and which describes the unexplained variance. In the growth–meat quality analysis, it increased markedly from the second root to the third, which suggests that only the first two roots can be used for further exploration. This is not the case for the carcass quality–meat quality analysis, where the strong relationship between carcass quality and meat quality reached the tenth root with good values for lambda prime. The growth–carcass quality analysis resembled the growth–meat quality analysis, such that in either case where growth variables were involved, the statistical quality of the canonical correlation was not as robust and thus had a lower capacity for prediction.

Table 3
General characteristics of the canonical correlation analysis among groups of variables.

Canonical analysis summaries	Independent variables	Dependent variables
Growth–meat quality		
No. of variables	6	17
Variance extracted, %	100.00	37.60
Total redundancy, %	49.96	14.92
Carcass quality–meat quality		
No. of variables	24	18
Variance extracted, %	84.24	100.00
Total redundancy, %	42.41	57.89
Growth–carcass quality		
No. of variables	6	24
Variance extracted, %	100.00	47.62
Total redundancy, %	78.36	37.93

In general, those variables included in the three stages of the goat meat production process were strongly correlated. Correlations were higher between sequential stages. Thus, the correlation between growth variables and carcass quality variables was stronger than that between growth variables and meat quality ones, and the correlation between carcass quality variables and meat quality variables was very strong.

Johnson, Brown, and Brown (1980) used the canonical correlation analysis to study the relationships between some post-weaning body measurements and performance in bulls. Yaprak, Koycegiz, Kutleca, Emsem, and Ockerman (2008) obtained similar results to those obtained in the present paper, although their study used body measurements, growth performance, and carcass traits in lambs. No study has been found that explores canonical correlations in goat meat production.

The level of correlation between groups of variables does not indicate that there are necessarily strong linear correlations among the individual variables included in one stage and those included in another. Linear correlations among single variables were beyond the purpose of the present paper, and for that reason they have not been explored here.

4. Conclusions

We have shown here the suitability of the multivariate analysis for developing a broad hypothesis in meat science. Canonical discriminant analysis and cluster analysis allowed us to distinguish among goat meat products of different origins (rearing systems) taking into account the whole production process and its integrated stages (growth, carcass quality, and meat quality).

High and statistically significant canonical correlations were found within the general framework of the production process among growth traits, carcass quality traits, and meat quality traits. Thus the final product results from the effects of the three stages; to get a good product, traits from all three stages must be taken into account.

In future studies, the capacity of prediction of the earliest variables (growth or perhaps morphological linear traits) with respect to the post-mortem variables will be explored, as was determined previously for sheep (Camacho et al., 2007).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at doi:10.1016/j.meatsci.2011.01.025.

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Las conclusiones finales *PRIMERA, SEGUNDA y TERCERA* se desprenden del artículo publicado en la REVISTA BRASILEIRA DE ZOOTECNIA; las conclusiones finales *CUARTA y SEXTA* se desprenden del artículo publicado en el JOURNAL OF APPLIED ANIMAL RESEARCH; las conclusiones finales *QUINTA y SEXTA* se desprenden de los artículos publicados en la revista REVISTA BRASILEIRA DE ZOOTECNIA y en el JOURNAL OF APPLIED ANIMAL RESEARCH; y las conclusiones finales *OCTAVA, NOVENA, DÉCIMA, UNDÉCIMA y DUODÉCIMA* se desprenden del artículo publicado en la revista MEAT SCIENCE.

PRIMERA.— Se demuestra que el sistema de explotación ejerce una marcada influencia en el crecimiento de los cabritos, siendo esencial el efecto que provoca la alimentación sobre los animales de cada sistema. En el presente estudio se aprecian comportamientos diferentes de crecimiento entre los distintos sistemas de explotación.

SEGUNDA.— La calidad de la canal de los cabritos resulta afectada por el sistema de explotación, y muestra de ello es que la canal de los cabritos procedentes del SILN es superior a la de los cabritos del SILA y del SE. Esto se deriva de dos hechos: sus canales son las que muestran mayores porcentajes de rendimiento comercial y real; y la contribución de los cortes principales al peso de la canal caliente es significativamente superior en los animales criados bajo el SILN que bajo los que fueron criados en el SILA o en el SE.

TERCERA.— Los efectos del sistema de explotación sobre las canales de los animales pueden alcanzar la fase de conservación. Las canales de los cabritos procedentes del SILA son las que están más desprotegidas ante los efectos negativos de la refrigeración sobre la canal al ser éstas las que poseen menores porcentajes de grasa, estando las canales de los cabritos del SILN y del SE más protegidas ante el frío gracias a sus mayores porcentajes de grasa superficial.

CUARTA.— La calidad de la carne también resulta afectada por el sistema de explotación, destacando el papel jugado por la alimentación tanto en los cabritos como en sus madres. Dos importantes características de la calidad de la carne, la terneza y el color de la carne, se vieron influenciadas por la alimentación recibida en el sistema de explotación ya que, mientras que la carne de los cabritos del SE fue de un color más intenso que en la de los otros cabritos, fruto principalmente al mayor contenido en hierro de la leche ingerida, la carne procedente de cabritos del SILN resultó ser la menos tierna, lo cual se debió al mayor contenido en colágeno y a la menor solubilidad del mismo.

QUINTA.— El pastoreo puede generar variaciones en algunas características de la calidad de la canal y de la calidad de la carne. Esto se sustenta en que los cabritos del SE, que fueron los únicos que pastaron, mostraron la mayor longitud de pierna de los tres sistemas, no habiendo diferencias estadísticamente significativas en la longitud de la pierna entre los cabritos del SILN y los del SILA. Además, esta actividad física dio lugar a que la carne de los cabritos del SE poseyera mayores porcentajes de ácido oleico.

SEXTA.— La carne de cabrito puede resultar muy beneficiosa para la salud debido a la presencia del ácido eicosapentanoico, cuyos beneficios para la salud humana han sido previamente demostrados. Incluso en este aspecto el sistema de explotación puede resultar determinante ya que la grasa intramuscular de los cabritos del SE fue la que presentó el menor índice de aterogenicidad, de manera que el consumo de la carne de cabritos del SE generará menores aumentos de colesterol en el plasma sanguíneo del consumidor.

SÉPTIMA.— La temprana edad al sacrificio hace que el dimorfismo sexual no se haga patente de forma estadísticamente significativa en lo que a crecimiento, calidad de la canal y calidad de la carne se refiere. Es por ello que, en cuanto a la producción de carne se refiere, el sexo no tiene que ser un factor a tener en cuenta por el ganadero en su toma de decisión a la hora de enviar los cabritos a sacrificio.

OCTAVA.— Se ha demostrado la conveniencia del análisis multivariado para el desarrollo de una hipótesis amplia en la ciencia de la carne. El análisis discriminante canónico y el análisis de conglomerados permiten distinguir los productos de carne de cabra resultantes de diferentes sistemas de cría, teniendo en cuenta tanto el proceso productivo en su conjunto como sus etapas integradas.

NOVENA.— La discriminación entre los sistemas de manejo resulta evidente tanto en el conjunto del proceso de producción de carne como en las fases que lo integran, si bien es cierto que la capacidad de discriminación de las variables involucradas en la fase de crecimiento fue menor, lo cual puede deberse al escaso margen de tiempo en que los cabritos se encuentran en la explotación antes de ser sacrificados. El análisis de la variabilidad entre todas las variables del proceso de producción también indica que los tres grupos podrían ser fácilmente diferenciados, lo cual se confirma a través de las distancias de Mahalanobis entre los tres grupos analizados. El análisis de conglomerados respalda la diferenciación entre los tres sistemas de explotación, observándose también cierta aproximación entre el SE y el SILA con respecto al SILN.

DÉCIMA.— La diferenciación entre grupos se reveló más claramente en las fases de calidad de la canal y de calidad de la carne y además, los resultados en cada fase fueron distintos: en la fase de calidad de la canal el sistema extensivo estaba claramente definido, y los otros dos mantenían cierto grado de indefinición en el espacio creado por los dos ejes; en la fase de calidad de la carne fue el grupo intensivo con lactancia artificial el que se encontraba mejor definido, si bien es cierto que en este caso los otros dos grupos mantuvieron una ligera definición en el espacio. De la interpretación de estos patrones de discriminación resulta que la canal se vio afectada negativamente por el sistema extensivo ya que mostraba parámetros que en general eran de menor calidad convencional. Sin embargo, en lo que a calidad de la carne se refiere, se mostró que la lactancia artificial perjudica dicha calidad ya que, de acuerdo con la valoración generalmente aceptada, la carne obtenida de los sistemas extensivo e intensivo con lactancia natural era de mejor calidad.

UNDÉCIMA.— Los resultados del análisis de correlación canónica entre las variables de las fases emparejadas (crecimiento–calidad de la canal, calidad de la canal–calidad de la carne, y crecimiento–calidad de la carne) confirman que las predicciones de las características *post–mortem* escogidas se pueden hacer sobre la base de modelos de regresión múltiple utilizando los pesos a diferentes edades y variables dependientes, lo cual resulta muy atractivo para la industria cárnica ya que permitirá identificar el tipo de explotación origen del producto final a partir de un conjunto de variables previamente establecidas.

DUODÉCIMA.— El producto final es el resultado de la influencia de las tres fases tal y como confirman las correlaciones canónicas elevadas y estadísticamente significativas encontradas dentro del marco general del proceso de producción entre las características de crecimiento, las características de la canal de calidad, y las características de la calidad de la carne. Por ello, para obtener un buen producto es fundamental que las tres fases sean tenidas en cuenta de una manera coordinada.

ANEXO I. OTRAS APORTACIONES CIENTÍFICAS DERIVADAS DIRECTAMENTE DE LA TESIS DOCTORAL

Publicaciones

2009. Zurita, P.; Camacho, M. E.; Pleguezuelos, J.; Delgado, J. V. Organic vs conventional herd effects on the weights and daily gains in Murciano–Granadina kids. Tropical and Subtropical Agroecosystems, 11, 98–99.

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Category Name	Total Journals in Category	Journal Rank in Category	Quartile in Category
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VETERINARY SCIENCES	145	76	Q3

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Category Name	Total Journals in Category	Journal Rank in Category	Quartile in Category
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Category Name	Total Journals in Category	Journal Rank in Category	Quartile in Category
FOOD SCIENCE & TECHNOLOGY	128	15	Q1