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Abstract

This study was designed to evaluate the effects of slaughter age (40 *vs.* 60 days) on slaughter performance, carcass and meat quality, and fatty acid composition of intramuscular and subcutaneous fat of Bergamasca lambs reared according to the traditional transhumant system in central Italy. Lambs slaughtered at 60 days of age had higher carcass weight (12.44 *vs.* 10.36 kg), lower dressing percentage (47.68% *vs.* 52.16%), and higher proportion of non-carcass components and leg commercial cut (37.82% *vs.* 35.49%). Furthermore, after 3 and 6 days of storage, the meat of older lambs showed lower drip loss (3.69% *vs.* 6.16%; 5.73% *vs.* 9.36%, respectively). Slaughter age did not influence meat pH, cooking loss, or chemical composition while older lambs had meat with higher a* (19.43 *vs.* 18.91). The fatty acid composition of intramuscular fat was not affected by slaughter age, except for C:13 and C:14 fatty acids, which were higher in older lambs. Subcutaneous fat of lambs slaughtered at 40 days of age showed a better fatty acid profile, as lower saturated fatty acids (52.46% *vs.* 55.68%) and higher mono- and polyunsaturated fatty acids (34.06% *vs.* 30.16%, 6.46% *vs.* 5.79%, respectively), and n-6 and n-3 polyunsaturated fatty acids. Furthermore, subcutaneous fat of lambs slaughtered at 40 days of age had better polyunsaturated/ saturated fatty acid ratio (0.12 *vs.* 0.11) and hypocholesterolemic/ hypercholesterolemic ratio (1.42 *vs.* 1.03), and lower atherogenic index (1.32 *vs.* 1.82) and thrombogenic index (1.98 *vs.* 2.35). For light lamb production using the traditional rearing systems, slightly heavier lambs can be produced without worsening chemical composition and cooking loss and fatty acid composition of the *longissimus lomborum* muscle. However, these lambs might have lower dressing percentages and a less favourable fatty acid profile of subcutaneous fat for human health.

Keywords: light lamb; slaughter age; carcass traits; meat quality.

1. Introduction

Traditional lamb production in Mediterranean countries is based on light lambs that are slaughtered at early ages (i.e., at 30 to 60 days of age), so just after weaning or after a short fattening period (Juárez et al., 2009; Santos-Silva et al., 2002a). These carcasses weigh up to 13 kg and are characterised by their pale pink colour, lower amounts of fat, and good flavour (Beriain et al., 2000), compared to heavier carcasses produced in other production systems and countries (Ekiz et al., 2013; Hajji et al., 2016; Jacques et al., 2011; Lind et al., 2009; Piasentier, 2003; Priolo et al., 2002).

In recent years, the demand for lean carcasses has grown due to increased awareness of consumers for healthy meat, with a focus on the quantity and quality of fat (Font i Fournols and Guerrero, 2014). Scientific studies and nutritional guidelines recommend not only a reduction in total fat intake in the human diet, but also a focus on saturated fatty acids (SFAs) and increased consumption of polyunsaturated fatty acids (PUFAs), and especially n-3 PUFAs (Calder and Yaqoob, 2009; World Health Organisation, 2003).

The age and weight of lambs at slaughter are among the main factors that affect the meat quality at both levels, in terms of the carcass and the meat. A greater weight usually implies an older lamb, except when the feed is manipulated or the lamb has periods of specific alimentary restrictions (Guerrero et al., 2013). Although greater slaughter age of lambs results in heavier carcasses, increased adiposity and better carcass conformation (D'Alessandro et al., 2013; Juárez et al., 2009), this can also result in increased intramuscular fat (Abdullah and Qudsieh, 2009; della Malva et al., 2016; Pérez et al., 2002). Furthermore, lambs slaughtered at a greater age can have a fatty acid (FA) composition of the meat that is less favourable for human health. This can arise as a result of increased SFAs, less PUFAs

and n-3 PUFAs, and increased atherogenic and thrombogenic indices (Cifuni et al., 2000; Marino et al., 2008; Santos-Silva et al., 2002b).

These aspects are of the utmost importance for the definition of strategies to enhance the production of lamb meat while also taking into consideration the market demand. In this sense, there are significant gaps of knowledge for lamb produced under quality labels, such as the Protected Geographical Indication of '*Agnello del Centro Italia*' (Lamb from Central Italy; European Union, Commission Regulation No. 475/2013). This can be produced using Bergamasca sheep, as well as some other sheep breeds.

Bergamasca sheep are an autochthonous Italian breed that originated from the Lombardy region (northern Italy) and that are traditionally raised according to the transhumant system (Piasentier, 2003). Nowadays, Bergamasca sheep are raised principally for meat in most parts of continental Italy (Bigi and Zanon, 2008), and they are often used for cross-breeding with other to improve meat yield. Male and female Bergamasca sheep can reach adult weights of 105 kg and 82 kg, respectively. In the Lombardy region, Bergamasca sheep are still the most important breed used to produce castrated, heavy and light lambs, as the traditional products of transhumant management (Piasantier et al., 2003).

In the Marche region (central Italy), lamb production is mainly based on extensive grazing and the transhumance is still of major importance. In summer, most of the flocks graze on upland pastures. Starting from autumn, the sheep are progressively transferred to lowlands, where until Spring the main forage resources are lucerne meadows, although green cereals, crop residues, marginal lands, and riverbanks are sometimes also used (Caballero et al., 2009; D'Ottavio and Santilocchi, 2014). Lamb production mainly occurs in the lowlands for the Easter and Christmas markets, which is when lamb meat is traditionally consumed in Italy (Cifuni et al., 2000). Lambs are reared on pastures with their dams until they reach the optimal slaughter weight, which according to local practices starts from 40 days of age. The

lambs are not weaned so their diet is mostly based on milk (i.e., to 20 days of age), while later they are supplemented with concentrate and/or hay, as needed.

The effects of slaughter age on the quality of light lamb meat has been studied for some Italian breeds, such as the Altamurana (della Malva et al., 2016; Marino et al., 2008), Apulian (Cifuni et al., 2000), Leccese (D'Alessandro et al., 2013), Trimeticcio (Marino et al., 2008) and Italian Merino (Oriani et al., 2005) sheep. However, there is little or no such information available for the lamb meat quality of the Bergamasca breed of sheep.

The aim of the present study was to evaluate the effects of slaughter age on slaughter performance, carcass traits and meat quality, including FA composition of intramuscular and subcutaneous fat, of Bergamasca light lambs reared under the traditional transhumant system of the Marche region of Italy.

2. Materials and methods

All animal handling followed the recommendations of European Union Directive 2010/63/EU, which are implemented in Italian law according to Legislative Decree No. 26/2014.

2.1. Experimental design, diet and animal management

This study was carried out from September to October 2015 in the Marche region (central Italy) under the standard conditions for rearing and management of the transhumant sheep system that is characteristic for this region. Twenty-two male, single-born, Bergamasca lambs were included in the study. At birth, the lambs were randomly distributed into two groups that were balanced for body weight. All of these lambs stayed with their dams on grasslands dominated by alfalfa (10.3 MJ metabolisable energy kg^{-1} dry matter [DM], 15.7% crude

protein DM, 28.5% crude fibre DM), and suckled their dams throughout the whole study period. The dams grazed and had free access to alfalfa hay (11.8 MJ metabolisable energy kg^{-1} DM, 15.2% crude protein DM, 22.3% crude fibre DM) and their diet was supplemented with corn grain (0.5 kg $head^{-1}$ day^{-1}; 16.5 MJ metabolisable energy kg^{-1} DM, 7.9% crude protein DM, 5.0% crude fibre DM). The lambs were given corn grain *ad libitum* in creep feeders from 20 days of age, and had access to alfalfa hay. The chemical compositions of collected feed samples were determined according to Martillotti et al. (1987). To calculate the average daily gain (ADG), the individual lamb weights were recorded at birth and after each 20 days, until slaughter. The lambs were slaughtered at two different ages: 11 lambs at an average of 40 days, and the other 11 lambs at an average of 60 days.

2.2. Slaughter procedure and assessment of carcass traits

To obtain the pre-slaughter weight, the lambs were weighed on the farm and soon after being transferred to a commercial slaughterhouse, where they were stunned and slaughtered by cutting the jugular vein. After the slaughter, the non-carcass components were removed and weighed (i.e., skin, head, feet, pluck [heart, lungs, liver, spleen], digestive tract). After chilling at 4 °C for 24 h, the cold carcass weights were recorded, and the dressing percentages were calculated. The right side of each carcass was jointed into three main commercial cuts: shoulder, whole loin with flank, and leg. The weights of each commercial cut were recorded and are expressed as proportions of the half carcass weight. For further analyses, the *longissimus lomborum* muscles between the first and sixth lumbar vertebrae were obtained.

2.3. Meat quality parameters

147 The pH of the *longissimus thoracis* muscle (between the tenth and thirteenth thoracic
148 vertebrae) was measured 45 min and 24 h (final pH) *post-mortem* using a portable pH meter
149 (XS pH 110; Eutech Instruments, Singapore) equipped with a penetrating glass electrode.

150 The drip loss and cooking loss were determined on approximately 80 g of 3-cm-thick
151 *longissimus lumborum* muscle. To measure the drip loss (ASPA, 1996), the meat samples
152 were weighed and wrapped in polyethylene bags. After 24 h storage at 4 °C, the samples were
153 gently dried with paper towels, and reweighed. This procedure was carried out as two
154 replications, and was repeated for the third and the sixth days of storage. For cooking loss
155 determination (ASPA, 1996), the meat samples were initially weighed, and then placed in
156 polyethylene bags and cooked in a water bath until they reached an internal temperature of 75
157 °C. The bags with the cooked meat samples where than cooled under cold running water for
158 30 min, and then they were removed from the bags, dried with paper towels, and reweighed.

159 The meat colour was assessed according to the CIELAB system (CIE, 1986), as the
160 lightness (L*), redness (a*) and yellowness (b*) of the *longissimus lumborum* muscle was
161 recorded for the fresh meat (~24 h *post-mortem*) using Minolta CR 200. A D65 illuminant
162 was used at an observation angle of 10° and with an aperture of 30 mm. The instrument was
163 calibrated using white and black standard coordinates. Chroma (C*; square root of [a^{*2} +
164 b^{*2}]) and hue angle (H°; $\tan^{-1}$ [b*/a*]) were also calculated. For each meat sample, three
165 colour measurements and calculations were performed for each parameter, and the means are
166 reported. After the colour measurements were performed, the meat samples were frozen (-20
167 °C), freeze-dried, ground and analysed for their chemical composition. The procedures
168 outlined by the AOAC (1999) were used to determine the DM (method ID 950.46), Kjeldahl
169 N (crude protein; method ID 981.10), fat (method ID 991.36) and ash (method ID 920.153).
170 Analyses were performed in duplicate for each sample, and the parameters and data are
171 corrected for moisture content.

172

173 *2.4. Fatty acid analysis*

174 The FA composition analysis was performed on freeze-dried samples of *longissimus*
175 *lomborum* muscle (i.e., intramuscular) fat and subcutaneous fat. The fat was extracted using a
176 Soxtec system with petroleum ether (boiling point range, 40-60 °C). The oven temperature for
177 both the pre- and post-extraction drying was within the temperature range suggested by Foss
178 for use with the Soxtec system, as 102 ±3 °C (Soxtec Avanti 2055 instruction manual). The
179 liquefied fat (~0.1 mL) was collected and dissolved in hexane (1.0 mL). The FA methyl esters
180 (FAMEs) were prepared by 'rapid' KOH-catalysed transesterification, according to method
181 ISO 12966-2:2011. The individual FAMEs were analysed on a gas chromatography system
182 (HRGC MEGA 2 series; Fisons Instruments, Milan, Italy) equipped with a Rt-2560 column
183 (length, 100 m, internal diameter, 0.25 mm; df, 0.2 μm; Restek, PA, USA) and a flame-
184 ionisation detector, with He as the carrier gas.

185 The identification of the FAs was based on comparisons of retention times with those
186 of commercial standards (Supelco 37 FAMEs Mix; Supelco, Bellefonte, PA, USA). The
187 concentrations of the individual FAMEs were expressed as percentages of the total FAMEs
188 identified, and also grouped as follows: SFAs, monounsaturated FAs (MUFAs) and PUFAs.
189 The PUFA/SFA and n-6/n-3 PUFA ratios were determined, along with the atherogenic and
190 thrombogenic indices (Ulbricht and Southgate, 1991) and the hypocholesterolemic/
191 hypercholesterolemic ratio (h/H; Fernández et al., 2007).

192

193 *2.5. Statistical analysis*

194 The data were analysed using the JMP software version 10 (SAS Institute Inc., Cary, NC,
195 USA, 1989-2007). Student's t-tests were used to evaluate effects of the two slaughter ages on
196 all of the parameters.

197

198 **3. Results and discussion**

199

200 The lamb growth performances are given in Table 1. When grouped per slaughter age,
201 the lambs did not differ in birth weight, weight at 20 and 40 days of age, and ADGs through
202 the different periods calculated. ADGs were higher than those reported by Santos-Silva et al.
203 (2002a) for Merino Branco and crossbred Ile de France x Merino Branco light lambs, reared
204 with dams on grass and with concentrate *ad libitum*. The effects of slaughter age on carcass
205 traits and non-carcass components are given in Table 2. As expected, the older lambs had
206 significantly higher pre-slaughter and carcass weights ($P < 0.001$, $P < 0.05$, respectively).
207 According to the European carcass classification system, and based on their average weights,
208 the carcasses from both of the age categories can be classified as class C for light lambs (10.1-
209 13.0 kg; European Union, 1994).

210 In agreement with previous studies (Cifuni et al., 2000; Morbidini et al., 1987),
211 increased slaughter age significantly decreased the dressing percentages of the light lambs (P
212 <0.001). This can be attributed to the significantly greater weight of offal of the lambs
213 slaughtered at 60 days of age, which negatively affected their dressing percentages. In
214 contrast, Polidori et al. (2017) reported higher dressing percentages for older lambs. These
215 data might be explained on the basis of the different slaughter weights used in these two
216 studies (Polidori et al., 23.8, 37.4 kg; present study, 19.84, 25.99 kg). In the present study, the
217 younger lambs were not functional as ruminants, whereas the older lambs had started to be,
218 which will thus have reduced their dressing percentages, as also explained by Cifuni et al.
219 (2000). As for the present study, D'Alessandro et al. (2013) reported significant differences in
220 carcass weight between Leccese lambs slaughtered at 45 and 60 days of age, although they
221 did not report any variations in dressing percentages. The dressing percentages of the lambs

slaughtered at 60 days of age were similar to those reported for heavy Bergamasca lambs (46.3%; Piasentier et al., 2001). However, the dressing percentages of the lambs from both of these age groups were lower than those reported for Leccese lambs slaughtered at 45 and 60 days (D'Alessandro et al., 2013) and for Apulian lambs slaughtered at 45 and 90 days of age (Cifuni et al., 2000).

For the non-carcass components, slaughter age influenced all of the parameters investigated (Table 2). The lambs slaughtered at 60 days of age had significantly greater ($P < 0.001$) proportions of head, skin, pluck and full digestive tract, and significantly lower ($P < 0.01$) proportions of feet, than the lambs slaughtered at 40 days of age. All of these differences can be attributed to the older slaughter age and the increased growth of the lambs.

As expected, the older lambs had significantly greater ($P < 0.01$) half-carcass weights than the younger lambs (Table 3). Furthermore, the lambs slaughtered at 60 days of age had significantly greater ($P < 0.01$) proportions of leg than the lambs slaughtered at 40 days of age, although the other commercial cuts did not differ between the slaughter ages. In a study by Cifuni et al. (2000), first grade wholesale lamb cuts (i.e., rack, loin, leg) were not significantly affected by slaughter age, while the proportions of second grade cuts (i.e., shoulder, neck, breast) decreased as age of slaughter increased. These data were attributed to the greater shoulder and breast proportions of the younger animals. The proportions of leg in the present study was higher than that reported by Skapetas et al. (2006) for lambs slaughtered at 45 and 60 days, while the proportions of shoulder were similar to those reported by Skapetas et al. (2006). Similar proportions of shoulder were reported by D'Alessandro et al. (2013) for lambs slaughtered in spring at a slaughter age of 45 days. However, contrary to the present data, D'Alessandro et al. (2013) obtained higher proportions of leg for Leccese lambs slaughtered at 45 days of age, compared to those slaughtered at 60 days of age. These contrary results

might be attributed to different methods used to dissect the carcasses into the main commercial cuts.

The age at slaughter did not affect the meat pH at 45 min and 24 h *post-mortem* (Table 4). These data are in agreement with other studies where the pHs obtained did not differ between light lambs slaughtered at different ages or weights (D'Alessandro et al., 2013; della Malva et al., 2016; Juárez et al., 2009). The final pHs were within the normal ranges (Tejeda et al., 2008) and were similar to those reported for light lambs of different breeds in other studies (D'Alessandro et al., 2013; della Malva et al., 2016; Juárez et al., 2009; Mazzone et al., 2010).

No differences were seen between the lambs slaughtered at 40 and 60 days of age in terms of drip loss measured after 1 day of meat storage (Table 4). The drip losses were lower than those reported for Appenninica light lambs (Mazzone et al., 2010). Differences in drip loss between lambs of the two slaughter ages appeared after the third day, and continued through the sixth day of storage, whereby the meat from the younger lambs had significantly higher ($P < 0.001$) drip loss than that from the older lambs. The results might be attributed to faster weakening of myofibrillar proteins by proteolytic enzymes during the storage of meat of younger lambs, thereby affecting the ability of myofibrillar proteins to hold water (Lawrie and Ledward, 2006). These data are in agreement with Russo et al. (2003), who reported better water-holding capacity for heavier carcasses due to lower drip loss after the second day of storage.

The cooking losses did not differ between the lambs slaughtered at 40 and 60 days of age (Table 4), and they were lower than those reported for light Appenninica lambs of similar slaughter age (Mazzone et al., 2010). On the contrary, although another method was used to determine their cooking loss, Russo et al. (2003) reported increased cooking losses with increased carcass weight. The lack of any differences in cooking losses between the lambs of

271 the two slaughter age groups in the present study can be explained on the basis that contrary
272 to Russo et al. (2003), the differences in the carcass weights between the age groups of these
273 light lambs were lower.

274 The meat chemical compositions of lambs slaughtered at 40 and 60 days of age are
275 given in Table 5. These data are comparable with those reported for light lambs of different
276 Italian breeds (D'Alessandro et al., 2013; della Malva et al., 2016; Mazzone et al., 2010).
277 Taking into consideration the intramuscular fat content, the meat analysed in the present study
278 was of good quality, on the basis that 2% to 3% of intramuscular fat ensures the desirable
279 organoleptic properties of the meat (Wood, 1990). No significant differences were recorded
280 for moisture, crude protein, fat and ash of the *longissimus lomborum* muscle in terms of the
281 slaughter ages.

282 These data are in agreement with other studies that have highlighted that the chemical
283 composition of lamb meat is not affected by slaughter age (D'Alessandro et al., 2013; Marino
284 et al., 2008) or carcass weight (Russo et al., 2003). In general, greater intramuscular fat has
285 been reported for older lambs of different breeds (Abdullah and Qudsieh, 2009; della Malva
286 et al., 2016; Juárez et al., 2009; Pérez et al., 2002).

287 In contrast to D'Alessandro et al. (2013), who observed no effects of slaughter age on
288 any of the meat colour parameters of light lambs, in the present study, some colour
289 differences were recorded (Table 5). Contrary to data reported for other breeds (Abdullah and
290 Qudsieh, 2009; della Malva et al., 2016; Juárez et al., 2009; Santos-Silva et al., 2002a;
291 Sañudo et al., 1996), in the present study, increased age and weight of the lambs did not result
292 in darker meat. Indeed, no differences were found for the lightness (L*), yellowness (b*) and
293 Hue and Chroma between the meat of the lambs slaughtered at 40 and 60 days of age. There
294 was significantly greater ($P < 0.01$) redness (a*) for the meat of the older and heavier lambs,
295 which is in agreement with other studies (della Malva et al., 2016; Juárez et al., 2009; Sañudo

et al., 1996). This can be explained by the higher myoglobin content in the meat of older lambs (Juárez et al., 2009). Furthermore, the colour differences for the meat from the lambs slaughtered at different ages might be due to the higher consumption of milk by the younger lambs, compared to the older ones that used proportionally more concentrate before their slaughter (Sañudo et al., 1996).

The FA compositions of the intramuscular and subcutaneous fat are given in Tables 6 and 7, respectively. In general, the intramuscular FA composition in the present study was similar to that reported by others for light lambs with high milk content in the diet (D'Alessandro et al., 2015; Cifuni et al., 2000; Oriani et al., 2005). The total SFAs were the most abundant FAs, followed by MUFAs and PUFAs.

Slaughter age had relatively small influences on the FA composition of *longissimus lomborum* muscle, whereby lambs slaughtered at 60 days of age had significantly greater ($P < 0.05$) tridecylic (C13:0) and palmitic (C16:0) SFAs than those slaughtered at 40 days of age (Table 6). The saturated palmitic FA has been shown to be hyperlipidemic (Bonamone and Grundy, 1988), and therefore consumption of meat from the younger lambs might reduce the risk of heart disease. This confirms data from other studies, where greater amounts of C16:0 were reported for the intramuscular fat of older and heavier lambs (Cifuni et al., 2000; D'Alessandro et al., 2015; della Malva et al., 2016; Santos-Silva et al., 2002b). However, the same studies reported better FA profile for the meat of the younger (less heavy) lambs, due to an increase in the proportion of SFAs with lamb growth. This reported trend for intramuscular fat was not evident in the present study, as the slaughter age did not affect any of the other single SFAs, MUFAs or PUFAs in the lamb intramuscular fat. Consequently, the nutritional indices of the meat, which are defined here as the PUFA/SFA, n-6/n-3 and h/H ratios and the atherogenic and thrombogenic indices, were similar between these Bergamasca lambs slaughtered at 40 and 60 days of age.

For the FA composition of the subcutaneous fat, there were much more evident effects of slaughter age (Table 7). Here, the lambs slaughtered at 40 days of age showed a better FA composition, in terms of significantly lower ($P < 0.01$) SFAs, and significantly greater ($P < 0.01$) MUFAs and PUFAs than the lambs slaughtered at 60 days of age. Unweaned lambs have a rumen that is only partially functional, and therefore their dietary unsaturated FAs are likely to be digested and adsorbed as in non-ruminants (Sañudo et al., 1998). In contrast, the older lambs start to consume a dry diet, which needs a more functional rumen to be digested. Consequently, the greater SFAs in the subcutaneous fat of the older lambs that here used proportionally more concentrate before their slaughter, will be due to the extensive hydrogenation by micro-organisms in the rumen.

In contrast to these data, Juárez et al. (2009) reported that for the FA composition of subcutaneous fat of suckling and light lambs, weight and age only influenced some of the individual SFAs, while the total SFAs, MUFAs and PUFAs, and the PUFA/SFA ratio, did not differ between the lambs of their two slaughter weights.

In the present study, the slaughter age affected the proportion of almost all of the SFAs investigated. In particular, the subcutaneous fat from the older lambs showed significantly greater proportions of capric (C10:0; $P < 0.01$), lauric (C12:0; $P < 0.05$), tridecylic ($P < 0.01$), myristic (C14:0; $P < 0.01$), pentadecanoic (C15:0; $P < 0.01$) and palmitic ($P < 0.001$) SFAs. It has been reported that short chain SFAs C12:0, C14:0 and C16:0 can increase plasma low-density lipoprotein (LDL)-cholesterol (Siri-Tarino et al., 2010). Therefore, the subcutaneous fat from the Bergamasca lambs slaughtered at 60 days showed less favourable levels of SFAs than that of lambs slaughtered at 40 days of age. On the other hand, the subcutaneous fat of the younger lambs had significantly greater heptadecanoic (C17:0; $P < 0.01$) and stearic (C18:0; $P < 0.001$) SFAs. However, although stearic acid is a saturated FA, it will not elevate

345 plasma LDL-cholesterol (Bonamone and Grundy, 1988) as it is poorly digested and can be
346 easily desaturated to oleic acid.

347 For the MUFAs, the lambs slaughtered at 40 days of age had significantly lower ($P < 0.01$)
348 myristoleic (C14:1) and palmitoleic (C16:1) acids, but significantly higher ($P < 0.01$)
349 sum of oleic and cis-vaccenic acid (∑C18:1c) in their subcutaneous fat, than the lambs
350 slaughtered at 60 days of age. Oleic acid has been reported to be hypolipidemic, which can
351 thus reduce plasma cholesterol and triglycerides (Mattson and Grundy, 1985). Therefore,
352 oleic acid can be considered as a desirable component of the diet (Baer et al., 2014).

353 The slaughter age also showed significantly greater ($P < 0.05$) proportions of single
354 PUFAs in the subcutaneous fat for the lambs slaughtered at 60 days, in terms of C18:2 trans
355 and C20:2 n-6. In agreement with Juárez et al. (2009), the older lambs showed significantly
356 lower linoleic acid (C18:2 n-6; $P < 0.001$). Furthermore, the essential linolenic acid (C18:3 n-
357 3) that has been shown to have positive health benefits was significantly lower ($P < 0.05$) in
358 the meat of the older lambs.

359 With the increased slaughter age, there were significantly decreased total PUFAs for
360 both the n-6 ($P < 0.001$) and n-3 ($P < 0.05$) PUFAs. However, the ratios between these (i.e., n-
361 6/n-3) did not differ for Bergamasca lambs between the two slaughter ages, and they both
362 remained within the recommended value for inclusion in a human diet (i.e., <4) (Wood et al.,
363 2003).

364 The lambs slaughtered at 40 days had subcutaneous fat that showed an improved
365 PUFA/SFA ratio, as this was significantly greater ($P < 0.01$) compared to the lambs
366 slaughtered at 60 days of age. However, the PUFA/SFA ratios of these slaughter age groups
367 were both low, and they did not reach the recommended value for human health (i.e., >0.4)
368 (Wood et al., 2003).

The overall changes in the FA compositions of the subcutaneous fat according to increased slaughter age showed significantly lower h/H ($P < 0.01$), which has a negative effect on the nutritional value of the meat. The subcutaneous fat of lambs slaughtered at 40 days of age also had significantly lower, and thus more favourable, atherogenic and thrombogenic indices ($P < 0.01$, $P < 0.001$, respectively), compared to the lambs slaughtered at 60 days of age.

4. Conclusions

The increase in the slaughter age for these Bergamasca lambs from 40 days to 60 days resulted in improved carcass weight, a greater proportion of leg commercial cut, and a lower drip loss after meat storage. For light lamb production using the traditional rearing systems, slightly heavier lambs can be produced without worsening chemical composition, cooking loss and fatty acid composition of the *longissimus lomborum* muscle. However, it is important to take in consideration that these heavier lambs might have lower dressing percentages and less favourable FA profile of their subcutaneous fat for human health.

For a more complete understanding of the effects of slaughter age on carcass and meat quality, additional studies are needed. These can be designed to evaluate more specifically the meat yield (i.e., from carcass or leg dissection), the effects of lamb nutrition (i.e., FA composition of feed and dams' milk), and the feed intake of the lambs.

389 **References**

390

391 Abdullah, A.Y., Qudsieh, R.I., 2009. Effect of slaughter weight and aging time on the quality
392 of meat from Awassi ram lambs. Meat Sci. 82, 309–316.
393 doi:10.1016/j.meatsci.2009.01.027

394 AOAC, 1999. Official method 950.46 moisture in meat; Official method 991.36 fat (crude) in
395 meat and meat products; Official method 981.10 crude protein in meat; Official method
396 920.153 ash in meat. In: Cunniff. P. (Ed.), Meat and Meat Products, vol. II. 16th ed.,
397 Official methods of analysis of the AOAC International, Gaithersburg, MD, pp. 1–15
398 (Chapter 39).

399 ASPA, 1996. Metodiche per la determinazione delle caratteristiche qualitative della carne.
400 Università di Perugia, Perugia, Italy.

401 Baer, D.J., Judd, J.T., Clevidence, B.A., Tracy, R.P., 2004. Dietary fatty acids affect plasma
402 markers of inflammation in healthy men fed controlled diets: a randomized crossover
403 study. Am. J. Clin. Nutr. 79, 969–973.

404 Beriain, M.J., Horcada, A., Purroy, A., Lizaso, G., Chasco, J., Mendizabal, J.A., 2000.
405 Characteristics of Lacha and Rasa Aragonesa lambs slaughtered at three live weights. J.
406 Anim. Sci. 78, 3070–3077.

407 Bigi, D, Zanon, A., 2008. Atlante delle razze autoctone italiane: Bovini, Equini, Ovicaprini,
408 Suini allevati in Italia. Edagricole Edizioni Agricole de il Sole 24 Ore, Milan.

409 Bonamone, A., Grundy, S.M., 1988. Effect of dietary stearic acid on plasma cholesterol and
410 lipoprotein levels. New Engl. J. Med. 318, 1244–1248.

411 Caballero R., Fernandez-Gonzalez F., Perez Badia R., Molle G., Roggero P.P., Bagella S.,
412 D'Ottavio P., Papanastasis V.P., Fotiadis G., Sidiropoulou A., Ipiloudis I., 2009. Grazing
413 systems and biodiversity in Mediterranean areas: Spain, Italy and Greece. Pastos 39, 9–

154.

Calder, P.C., Yaqoob, P., 2009. Omega-3 polyunsaturated fatty acids and human health outcomes. Biofactors. 35, 266–272.

CIE, 1986. Colorimetry, 2nd ed. Vol. nº 15.2. Centre International de L'eclairage, Vienna.

Cifuni, G., Napolitano, F., Pacelli, C., Riviezzi, A., Girolami, A., 2000. Effect of age at slaughter on carcass traits, fatty acid composition and lipid oxidation of Apulian lambs. Small Rumin. Res. 35, 65–70. doi: 10.1016/s0921-4488(99)00060-7

D'Alessandro, A.G., Maiorano, G., Ragni, M., Casamassima, D., Marsico, G., Martemucci, G., 2013. Effects of age and season of slaughter on meat production of light lambs: Carcass characteristics and meat quality of Leccese breed. Small Rumin. Res. 114, 97–104. doi:10.1016/j.smallrumres.2013.05.006

D'Alessandro, A.G., Palazzo, M., Petrotos, K., Goulas, P., Martemucci, G., 2015. Fatty acid composition of light lamb meat from Leccese and Comisana dairy breeds as affected by slaughter age. Small Rumin. Res. 127, 36–43. doi:10.1016/j.smallrumres.2015.04.004

D'Ottavio, P., Santilocchi, R., 2014. Mountain areas of the Marche Region (Central Apennine), in: Huyghe, C., De Vliegher, A., Van Gils, B., Peeters, A. (Eds.), Grasslands and herbivore production in Europe and effects of common policies. Éditions Quæ, pp. 179–183.

della Malva, A., Albenzio, M., Annicchiarico, G., Caroprese, M., Muscio, A., Santillo, A., Marino, R., 2016. Relationship between slaughtering age, nutritional and organoleptic properties of Altamurana lamb meat. Small Rumin. Res. 135, 39–45. doi:10.1016/j.smallrumres.2015.12.020

Ekiz, B., Demirel, G., Yilmaz, A., Ozcan, M., Yalcintan, H., Kocak, O., Altinel, A., 2013. Slaughter characteristics, carcass quality and fatty acid composition of lambs under four different production systems. Small Rumin. Res. 114, 26–34.

doi:10.1016/j.smallrumres.2013.05.011

European Union, 1994. European Community Standard for the Classification of Light Lambs Carcasses, Brochure No. CM-84-94-703-ES-D. Publishing Bureau of the European Communities, L-2985 Luxembourg.

Fernández, M., Ordóñez, J.A., Cambero, I., Santos, C., Pin, C., de la Hoz, L., 2007. Fatty acid compositions of selected varieties of Spanish dry ham related to their nutritional implications. Food Chem. 101, 107–112. doi:10.1016/j.foodchem.2006.01.006

Font i Fournols, M., Guerrero, L., 2014. Consumer preferences, behaviour and perception about meat and meat production: An overview. Meat Sci. 98, 361–371.

Guerrero, A., Valero, M.V., Campo, M.M., Sañudo, C., 2013. Some factors that affect ruminant meat quality: from the farm to the fork. Review. Acta Sci. Anim. Sci. 35, 335-347. doi: 10.4025/actascianimsci.v35i4.21756. Acta Sci. Anim. Sci. 35, 335–347.

Hajji, H., Joy, M., Ripoll, G., Smeti, S., Mekki, I., Gahete, F.M., Mahouachi, M., Atti, N., 2016. Meat physicochemical properties, fatty acid profile, lipid oxidation and sensory characteristics from three North African lamb breeds, as influenced by concentrate or pasture finishing diets. J. Food Compos. Anal. 48, 102–110. doi:10.1016/j.jfca.2016.02.011

ISO 12966-2:2011. Animal and vegetable fats and oils - Gas chromatography of fatty acid methyl esters-Part 2: Preparation of methyl esters of fatty acids.

Jacques, J., Berthiaume, R., Cinq-Mars, D., 2011. Growth performance and carcass characteristics of Dorset lambs fed different concentrates: Forage ratios or fresh grass. Small Rumin. Res. 95, 113–119. doi:10.1016/j.smallrumres.2010.10.002

JMP, Version 10. SAS Institute Inc., Cary, NC, 1989-2007.

Juárez, M.M., Horcada, A., Alcalde, M.J., Valera, M., Polvillo, O., Molina, A., 2009. Meat and fat quality of unweaned lambs as affected by slaughter weight and breed. Meat Sci.

83, 308–313. doi:10.1016/j.meatsci.2009.05.017

Lawrie, R. A., Ledward, D. A., 2006. Lawrie's Meat Science. Seventh English, edition ed. Cambridge England: Woodhead Publishing Limited.

Lind, V., Berg, J., Eik, L.O., Mølmann, J., Haugland, E., Jørgensen, M., Hersleth, M., 2009. Meat quality of lamb: Pre-slaughter fattening on cultivated or mountain range pastures. Meat Sci. 83, 706–712. doi:10.1016/j.meatsci.2009.08.008

Marino, R., Albenzio, M., Annicchiarico, G., Caroprese, M., Muscio, A., Santillo, A., Sevi, A., 2008. Influence of genotype and slaughtering age on meat from Altamurana and Trimeticcio lambs. Small Rumin. Res. 78, 144–151. doi:10.1016/j.smallrumres.2008.06.002

Martillotti, F., Antongiovanni, M., Rizzi, L., Santi, E., Bittante, G., 1987. Metodi di analisi per la valutazione degli alimenti d'impiego zootecnico. Quaderni metodologici N. 8. IPRA, CNR, Rome.

Mattson, F.M., Grundy, S.M., 1985. Comparison of effects of dietary saturated, monounsaturated, and polyunsaturated fatty acids on plasma lipids and lipoproteins in man. J. Lipid Res. 26, 194–202.

Mazzone, G., Giammarco, M., Vignola, G., Sardi, L., Lambertini, L., 2010. Effects of the rearing season on carcass and meat quality of suckling Apennine light lambs. Meat Sci. 86, 474–478. doi:10.1016/j.meatsci.2010.05.037

Morbidini, L., Panella, F., Polidori, P., Sarti, D.M., 1987. Observation on productivity of Apennine sheep. Z.N.A. 13, 147–155.

Oriani, G., Maiorano, G., Filetti, F., Di Cesare, C., Manchisi, A., Salvatori, G., 2005. Effect of age on fatty acid composition of Italian Merino suckling lambs. Meat Sci. 71, 557–562. doi:10.1016/j.meatsci.2005.04.040

Pérez, P., Maino, M., Tomic, G., Mardones, E., Pokniak, J., 2002. Carcass characteristics and

meat quality of Suffolk Down suckling lambs. Small Rum. Res. 44, 233–240.

Piasentier, E., 2003. The effect of grazing on the quality of lamb meat. International Fachtagung Für Schafhaltung. Innsbruck.

Piasentier, E., Valusso, R., Gasperi, F., 2001. Effect of production system on the carcass and meat quality of Bergamasca lamb. In: Proceedings of the ASPA XIV Congress "Recent Progress in Animal Production Science", Firenze (Italy), June 12-15, 2001. Pp. 550-552.

Polidori, P., Pucciarelli, S., Cammertoni, N., Polzonetti, V., Vincenzetti, S., 2017. The effects of slaughter age on carcass and meat quality of Fabrianese lambs. Small Rumin. Res. 155, 12–15. doi:10.1016/j.smallrumres.2017.08.012

Priolo, A., Micol, D., Agabriel, J., Prache, S., Dransfield, E., 2002. Effect of grass or concentrate feeding systems on lamb carcass and meat quality. Meat Sci. 62, 179–185. doi:10.1016/S0309-1740(01)00244-3

Russo, C., Prziuso, G., Verità, P., 2003. EU carcass classification system: Carcass and meat quality in light lambs. Meat Sci. 64, 411–416. doi:10.1016/S0309-1740(02)00209-7

Santos-Silva, J., Mendes, I.A., Bessa, R.J.B., 2002a. The effect of genotype, feeding system and slaughter weight on the quality of light lambs: 1. Growth, carcass composition and meat quality. Livest. Prod. Sci. 76, 17–25.

Santos-Silva, J., Bessa, R.J.B., Santos-Silva, F., 2002b. Effect of genotype, feeding system and slaughter weight on the quality of light lambs. II. Fatty acid composition of meat. Livest. Prod. Sci. 77, 187–194. doi:10.1016/S0301-6226(02)00059-3

Sañudo, C., Santolaria, M.P., Maria, G., Osorio, M., Sierra, I., 1996. Influence of carcass weight on instrumental and sensory lamb meat quality in intensive production systems. Meat Sci. 42, 195–202.

Sañudo, C., Sierra, I., Olleta, J.L., Martin, L., Campo, M.M., Santolaria, P., Wood, J.D., Nute, G.R., 1998. Influence of weaning on carcass quality, fatty acid composition and meat

514 quality in intensive lamb production system. Anim. Sci. 66, 175–187
515 Siri-Tarino, P.W., Sun, Q., Hu, F.B., Krauss, R.M., 2010. Saturated fatty acids and risk of
516 coronary heart disease: modulation by replacement nutrients. Curr Atheroscler. Rep. 12,
517 384–390.
518 Skapetas, B., Sinapis, E., Hatziminaoulglou, J., Karalazos, A., Katanos, J., 2006. Effect of age
519 at slaughter on carcass characteristics and carcass composition in lambs of mountain
520 Greek breed. Czech J. Anim. Sci. 51, 311–317.
521 Tejeda, J.F., Pena, R.E., Andres, A.I., 2008. Effect of live weight and sex on physico-
522 chemical and sensorial characteristics of Merino lamb meat, Meat Sci. 80, 1061–1067.
523 Ulbricht, T.L.V., Southgate, D.A.T., 1991. Coronary heart disease: seven dietary factors.
524 Lancet 338, 985–992. doi:10.1016/0140-6736(91)91846-M
525 Wood, J.D., Richardson, R.I., Nute, G.R., Fisher, A.V., Campo, M.M., Kasapidou, E., Sheard,
526 P.R., Enser, M., 2003. Effects of fatty acids on meat quality: a review. Meat Sci. 66, 21–
527 32.
528 Wood, J.D., 1990. Consequences for meat quality of reducing carcass fatness. In: Wood, J.D.
529 Fisher, A.V. (Eds.), Reducing Fatness in Meat Animals. Elsevier Applied Science,
530 London, UK, 344–1035.
531 World Health Organisation, 2003. Diet, nutrition and the prevention of chronic disease.
532 Report of a joint WHO/FAO expert consultation 916.
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540 **Table 1**

541 Growth performance of Bergamasca lambs slaughtered at 40 and 60 days of age (means ±

542 SD).

	Slaughter age (days)		Significance
	40	60	
Live Weight (kg)			
Birth	5.37 ± 1.05	5.11 ± 0.83	NS
20 days	11.79 ± 2.25	11.77 ± 1.22	NS
40 days	19.84 ± 3.07	19.59 ± 2.35	NS
60 days		25.95 ± 3.34	
Average Daily Gain (g d^{-1})			
birth to 20 days	318 ± 73.19	337 ± 72.57	NS
20 to 40 days	383 ± 56.82	373 ± 63.01	NS
total rearing period	351 ± 60.23	337 ± 61.93	NS

543 NS: not significant, $P > 0.05$

544

Table 2

Carcass traits and non-carcass components of Bergamasca lambs slaughtered at 40 and 60 days of age (means ± SD).

	Slaughter age (days)		Significance
	40	60	
Pre-slaughter weight (kg)	19.84 ± 3.07	25.95 ± 3.34	***
Cold carcass weight (kg)	10.36 ± 1.75	12.44 ± 2.14	*
Cold dressing (%)	52.16 ± 2.50	47.68 ± 2.65	***
Proportion (%) on PSW			
Head	2.63 ± 0.23	3.92 ± 0.32	***
Skin	9.09 ± 0.60	11.54 ± 0.85	***
Feet	1.01 ± 0.11	0.83 ± 0.10	**
Pluck	5.39 ± 0.93	7.69 ± 0.44	***
Full digestive tract	13.86 ± 2.30	17.96 ± 2.94	***

PSW: pre-slaughter weight.

* $P < 0.05$.

** $P < 0.01$.

*** $P < 0.001$.

553 **Table 3**

554 Half carcass weight and proportions of commercial cuts of Bergamasca lambs slaughtered at

555 40 and 60 days of age (means ± SD).

	Slaughter age (days)		Significance
	40	60	
Half carcass weight (kg)	4.80 ± 0.85	6.06 ± 1.07	**
Proportions of commercial cuts (%)			
Shoulder	19.81 ± 0.88	19.53 ± 1.36	NS
Whole loin with flank	44.69 ± 1.71	42.65 ± 2.84	NS
Leg	35.49 ± 1.06	37.82 ± 1.85	**

556 NS: not significant, $P > 0.05$.

557 ** $P < 0.01$.

558

559 **Table 4**

560 pH, drip loss and cooking loss of Bergamasca lambs slaughtered at 40 and 60 days of age

561 (means ± SD).

	Slaughter age (days)		Significance
	40	60	
pH			
45 min	6.41 ± 0.14	6.54 ± 0.35	NS
24 h	5.71 ± 0.11	5.69 ± 0.14	NS
Drip loss (%)			
1 day	0.77 ± 0.17	1.01 ± 0.53	NS
3 days	6.16 ± 1.41	3.69 ± 0.97	***
6 days	9.36 ± 1.45	5.73 ± 1.16	***
Cooking loss (%)	12.22 ± 3.85	10.53 ± 4.94	NS

562 NS: not significant, $P > 0.05$.

563 *** $P < 0.001$.

564 **Table 5**

565 Chemical composition and colour of *longissimus lomborum* muscle of Bergamasca lambs

566 slaughtered at 40 and 60 days of age (means ± SD).

	Slaughter age (days)		Significance
	40	60	
Chemical composition (%)			
Moisture	73.45 ± 1.35	74.55 ± 1.56	NS
Crude Protein	19.98 ± 0.50	19.68 ± 0.62	NS
Fat	2.70 ± 1.11	2.15 ± 0.91	NS
Ash	1.31 ± 0.07	1.39 ± 0.25	NS
Colour parameters			
L*	41.52 ±.2.13	41.11 ± 3.07	NS
a*	18.91 ± 1.59	19.43 ± 1.21	*
b*	3.3 ± 0.55	3.43 ± 0.93	NS
Hue	0.17 ± 0.03	0.18 ± 0.05	NS
Chroma	30.2 ± 4.61	32.13 ± 8.19	NS

567 NS: not significant, $P > 0.05$.

568 ** $P < 0.01$.

569

570 **Table 6**

571 Fatty acid composition (% of total fatty acids) of *longissimus lomborum* muscle of

572 Bergamasca lambs slaughtered at 40 and 60 days of age (means ± SD).

	Slaughter age (days)		Significance
	40	60	
C10:0	0.64 ± 0.24	0.75 ± 0.18	NS
C11:0	0.04 ± 0.01	0.04 ± 0.01	NS
C12:0	1.53 ± 0.57	1.84 ± 0.50	NS
C13:0	0.10 ± 0.03	0.12 ± 0.02	**
C14:0	9.78 ± 1.90	10.77 ± 2.05	NS
C15:0	0.97 ± 0.17	1.01 ± 0.15	NS
C16:0	24.43 ± 1.84	26.09 ± 0.90	**
C17:0	1.20 ± 0.17	1.12 ± 0.10	NS
C18:0	11.98 ± 1.72	11.18 ± 1.79	NS
C20:0	0.10 ± 0.04	0.08 ± 0.03	NS
C21:0	0.15 ± 0.07	0.16 ± 0.03	NS
C14:1	0.29 ± 0.11	0.34 ± 0.11	NS
C16:1 n-7	1.78 ± 0.40	1.90 ± 0.32	NS
C17:1	0.55 ± 0.14	0.55 ± 0.10	NS
∑18:1t[1]	3.31 ± 1.59	3.05 ± 1.21	NS
∑18:1c[1]	30.14 ± 3.68	28.12 ± 3.29	NS
∑18:2t[1]	1.58 ± 0.26	1.65 ± 0.27	NS
C18:2 n-6	4.2 ±1.36	3.56 ± 0.83	NS
C18:2 *cis*-9, *trans*-11(CLA)	1.50 ± 0.30	1.64 ± 0.40	NS
C18:3 n-3	1.57 ± 0.32	1.53 ± 0.24	NS
C20:2 n-6	0.09 ± 0.03	0.07 ± 0.01	NS
C20:4 n-6	0.53 ± 0.39	0.63 ± 0.29	NS
C20:5 n-3	0.26 ± 0.19	0.29 ± 0.12	NS
C22:5 n-3	0.34 ± 0.23	0.36 ± 0.14	NS
C22:6 n-3	0.14 ± 0.10	0.14 ± 0.07	NS
Other fatty acids	2.79 ± 0.26	2.99 ± 0.19	NS
SFA	50.91 ± 3.89	53.17 ± 2.35	NS
MUFA	32.76 ± 3.97	30.91 ± 3.49	NS
PUFA	8.64 ± 2.46	8.23 ± 1.32	NS
n-6 PUFA	4.82 ± 1.67	4.27 ± 1.01	NS
n-3 PUFA	2.32 ± 0.82	2.33 ± 0.50	NS
n-6/n-3 PUFA	2.13 ± 0.59	1.88 ± 0.53	NS
PUFA/SFA	0.17 ± 0.06	0.16 ± 0.02	NS
h/H	1.11 ± 0.21	0.95 ± 0.15	NS
AI	1.66 ± 0.40	1.92 ± 0.35	NS
TI	1.79 ± 0.31	1.92 ± 0.17	NS

573 ∑C18:1t: sum of unidentified C18:1 *trans* isomers; ∑C18:1c: C18:1Δ9c + Δ11c; ∑C18:2t,

574 18:2 n-6 c,t + t,c + t,t; SFA: saturated fatty acids; MUFA: monounsaturated fatty acids;

575 PUFA: polyunsaturated fatty acids; n-6 PUFA: omega 6 fatty acids; n-3 PUFA: omega 3 fatty

576 acids; PUFA/SFA: polyunsaturated/ saturated fatty acid ratio; h/H: hypocholesterolemic/
577 hypercholesterolemic ratio (Fernández et al., 2007); AI: atherogenic index (Ulbricht and
578 Southgate, 1991); TI: thrombogenic index (Ulbricht and Southgate, 1991); NS: not
579 significant, $P > 0.05$.; ** $P < 0.01$.
580

Table 7

Fatty acid composition (% of total fatty acids) of subcutaneous adipose tissue of Bergamasca lambs slaughtered at 40 and 60 days of age (means ± SD).

	Slaughter age (days)		Significance
	40	60	
C10:0	0.63 ± 0.18	0.86 ± 0.11	**
C11:0	0.03 ± 0.01	0.04 ± 0.01	**
C12:0	1.09 ± 0.39	1.50 ± 0.30	*
C13:0	0.06 ± 0.02	0.08 ±0.02	**
C14:0	7.42 ± 1.55	9.28 ± 1.24	**
C15:0	0.72 ±0.18	0.90 ±0.09	**
C16:0	19.58 ± 2.13	22.99 ± 1.51	***
C17:0	1.73 ± 0.17	1.51 ± 0.06	**
C18:0	20.94 ± 2.23	18.23 ± 1.68	**
C20:0	0.17 ± 0.03	0.17 ± 0.05	NS
C21:0	0.09 ± 0.03	0.10 ± 0.01	NS
C14:1	0.10 ± 0.02	0.14 ±0.02	**
C16:1 n-7	0.80 ± 0.09	0.94 ± 0.12	**
C17:1	0.42 ± 0.06	0.39 ± 0.06	NS
∑18:1t[1]	2.84 ± 2.14	3.82 ± 1.79	NS
∑18:1c[1]	32.74 ± 2.93	28.69 ± 2.51	**
∑18:2t[1]	1.59 ± 0.15	1.72 ± 0.14	*
C18:2 n-6	2.92 ± 0.33	2.44 ± 0.14	***
C18:2 *cis*-9, *trans*-11(CLA)	1.71 ± 0.29	1.71 ± 0.20	NS
C18:3 n-3	1.57 ± 0.26	1.37 ± 0.11	*
C20:2 n-6	0.03 ± 0.01	0.04 ± 0.01	*
C20:4 n-6	0.05 ± 0.01	0.05 ± 0.02	NS
C20:5 n-3	0.02 ± 0.01	0.02 ± 0.01	NS
C22:5 n-3	0.12 ± 0.02	0.13 ± 0.03	NS
C22:6 n-3	0.04 ± 0.01	0.03 ± 0.02	NS
Other fatty acids	2.59 ± 0.26	2.83 ± 0.10	*
SFA	52.46 ± 2.60	55.68 ± 2.33	**
MUFA	34.06 ± 2.93	30.16 ± 2.53	**
PUFA	6.46 ± 0.62	5.79 ± 0.34	**
n-6 PUFA	3.00 ± 0.33	2.52 ± 0.13	***
n-3 PUFA	1.75 ± 0.27	1.56 ± 0.09	*
n-6/n-3 PUFA	1.73 ± 0.15	1.62 ± 0.09	NS
PUFA/SFA	0.12 ± 0.01	0.11 ± 0.01	**
h/H	1.42 ± 0.29	1.03 ± 0.15	**
AI	1.32 ± 0.31	1.82 ± 0.30	**
TI	1.98 ± 0.06	2.35 ± 0.07	***

∑C18:1t: sum of unidentified C18:1 *trans* isomers; ∑C18:1c: C18:1Δ9c + Δ11c; ∑C18:2t, 18:2 n-6 c,t + t,c + t,t; SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; n-6 PUFA: omega 6 fatty acids; n-3 PUFA: omega 3 fatty

587 acids; PUFA/SFA: polyunsaturated/ saturated fatty acid ratio; h/H: hypocholesterolemic/
588 hypercholesterolemic ratio (Fernández et al., 2007); AI: atherogenic index (Ulbricht and
589 Southgate, 1991); TI: thrombogenic index (Ulbricht and Southgate, 1991); NS: not
590 significant, P >0.05.; * P <0.05; ** P <0.01; *** P <0.001.
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