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Effects of the rearing season on carcass and meat quality of suckling Apennine light lambs

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ABSTRACT

The aim of this study was to evaluate the effects of the rearing season (autumn vs winter) on the carcass and meat quality of light lambs, obtained according to the traditional farming system usual in central Italy. Eighty carcasses from 60 d ± 3 old unweaned Apennine single birth male lambs, permanently reared indoor, half in autumn (receiving milk from ewes permanently pastured) and half in winter (which dams did never acceded to pasture), were weighed, classified according to the EU classification system for light lambs, and their *Longissimus lumborum* meat was analysed for pH, colour, drip and cooking losses, proximate composition and fatty acids profile of intramuscular fat. Most of the carcasses fully responded to the 1st quality EU requirements and no effects of the rearing season was evident on carcass characteristics. On the contrary, *L. lumborum* of lambs born and reared in autumn, receiving milk from ewes permanently pastured, evidenced a lower Lightness L* ($P = 0.02$), a higher Chroma C* ($P = 0.01$), with a higher fat content ($P = 0.04$) than lambs reared in winter, which dams were permanently stall-fed. Moreover the intramuscular fat of the former was characterized by a greater PUFA concentration ($P = 0.01$), a more favourable *n*-6/*n*-3 ratio ($P < 0.001$), and a higher CLA content ($P < 0.001$) than the latter, as a result of the difference related to the sheep traditional feeding system.

1. Introduction

In Central Italy, a semi-extensive farming system, mainly of Apennine breed or its crossbreeds, is widely practiced to produce a traditional lamb slaughtered at about 60 days of age (Panella & Di Felice, 1996). The rearing system, similar to others in Mediterranean area, is quite well characterized, planning slaughtering around Easter and Christmas, following the ancient tradition among the Christians to use lamb meat as a popular food at these times, and envisaging the use of pasture as long as possible for the sheep while lambs, permanently reared into the sheepfold, are fed on their mothers' milk during the whole production, receiving a hay and concentrates supplement from 25–30 days to slaughter.

If high moisture content and low fat levels, pale-pink color, mild flavor and tenderness are distinctive characteristics of suckling-lamb meat (Teixeira, Batista, Delfa & Cadavez, 2005; Santos, Silva, Mena & Azevedo, 2007), time of birth and time of slaughter, due to the variability of the environmental conditions and differences in the availability and quality of feeding resources, could also affect carcass and meat quality. It has been observed that animals born in winter are somewhat darker (Alexandrova, Banskalieva, Angelov, Ivanov, Laleva & Slavova, 1996) and those slaughtered in winter somewhat more tender and leaner than those slaughtered in autumn (Ellis, Webster, Merrell & Brown, 1997). Few data are however available on carcass and meat peculiarities of unweaned lambs as influenced by seasonal practices when typical extensive rearing systems are applied. So, aim of this study has been to evaluate the influence of the rearing season (autumn, when lambs receive milk from ewes permanently pastured and winter, when lambs dams do never accede to pasture) on some carcass and meat traits of suckling Apennine lambs (the third meat ovine breed in Italy in terms of population size, with estimated mature weight of 70–80 and 50–60 kg for males and females, respectively) obtained according to a traditional farming system in the Abruzzo region, representing the type commonly slaughtered in Central Italy.

2. Materials and methods

2.1. Animals

Eighty Apennine male lambs, from single birth, 60 days ± 3 old, were randomly purchased, half at Christmas and half at Easter, from the same breeder of the Abruzzo region, transported to slaughterhouse according to EU regulations (Council Regulation, EEC No 1/, 2005), travelling on average 35 km, and immediately slaughtered.

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All the lambs had been reared according to the traditional farming system used in Central Italy. Particularly, lambs slaughtered at Christmas (autumn lambs) were reared permanently into the sheepfold and fed at evening and night on their mothers' milk during the whole growing period, receiving in a creep way *ad lib* from 25 to 30 days to slaughter lucerne hay and a cereal based supplement, while their dams were pastured in extensive areas of hills (at an altitude varying from 300 to 900 m, with wide variations in food supply) from midmorning to evening. Conversely, lambs born in winter and slaughtered at Easter (winter lambs) were reared similarly into the sheepfold together with their mothers, that however did never acceded to pasture and received a ration based on meadow hay and concentrate supplementary foods (mainly cereals).

2.2. Sampling and measurements

Each reference carcass (obtained following the Reg. EEC n. 2137/92: whole body as presented after bleeding, evisceration and skinning, without the head, the feet, the tail, the udder, the genitalia, the liver and the pluck; kidneys and kidney fat are included in the carcass), was immediately weighed (reference carcass weight – RCW). Degree of fatness (1 low–4 high) was assessed by a qualified assessor using the EU photographic standards (Council Regulation EEC n., 2137/92 and Council Regulation EEC n. 461/93) and the carcasses were then classified, just after weighing, according to the same EU classification system for light lambs.

M. longissimus lumborum pH was measured, *in situ*, at 45 min *post mortem* (pH_1), before entering the cooling room, on the right side between the 5th and the 6th lumbar vertebra (A.S.P.A., 1996) using a penetrating electrode adapted to a portable pH meter (Crison pH-metro 507 and a 52–32 spear electrode, Crison Instruments, Spain).

Carcasses were then cooled at 4 °C for 24 h and ultimate pH (pHu) was determined *in situ* using the same instruments on the same muscle.

Meat colour parameters (L*, Chroma*, Hue°) were successively measured on the cross-section of the *L. lumborum* muscle on the right side, according to the CIELab system, using a Minolta Chroma Meter CR-300 (Minolta Camera Co., Osaka, Japan). Colour measurements were made on freshly cut surfaces and represent the mean of 3 measurements performed on the cross-section of the muscle.

On meat samples of about 50 g each and roughly cubic in shape from *L. lumborum* muscle, drip and cooking losses were determined using the methods suggested by Honikel (1998).

Further individual samples of loin muscle were then used for moisture, fat, protein and ash analysis (AOAC Official Methods no. 950.46, 991.36, 981.10 and 920.153, respectively; AOAC, 1999).

Finally, from the same muscle, intramuscular lipids were extracted following the protocol suggested by Folch, Lees and Slogane Stanley (1957). From the extract the fatty acid profile was determined, after performing cold methilation of fatty acids with the technique proposed by Fraga and Lerker (1984). This determination was accomplished by gas chromatography, using a capillary column Chrompack CP-SIL 88 (100 m length, 0.2 μm film thickness, 0.25 mm inner diameter), working from 160 °C (1 min) to 175 °C (4 °C/min) for a total of 28 min, then, from 175 °C to 215 °C (5 °C/min) for 35 min with injector at 250 °C and detector at 260 °C and using a ionised flame detector.

2.3. Statistical analysis

All the data were processed by a Oneway analysis of variance using the procedure of SPSS version 13.0 statistical package (SPSS, 2006) and considering the rearing season (autumn and winter; 1 d.f.) as source of variation. The number of carcasses classified within the same category between the 2 different rearing seasons were compared using a chi-square test.

3. Results and discussion

3.1. Slaughter and carcass characteristics

Carcass characteristics are reported in Table 1. The average general carcass weight (as reference carcass) was 9.69 kg (±1.72) which is consistent with the weight usually achieved by the Apennine breed (used in this study) or its crossbreeds, slaughtered at similar age in Central Italy (Sarti, Morbidini & Panella, 1991).

While 4 carcasses at Christmas and 3 at Easter exceeded the limit of 13 kg, almost the half (47.9%) of the remaining were included in the range of 7.1 kg and 10.0 kg (category B of the EU classification system for light lambs). The 45.2% had a weight between 10.1 kg and 13.0 kg (category C) while 6.8% did not exceed 7.0 kg, falling in category A.

All the carcasses had a pink or pale pink colour of meat (determined on the flank at the *rectus abdominis* by reference to a standardised colour chart). In view of fat coverage, mean fatness degree was 2.18; 64 carcasses (87.7%) were classified as 1st quality (fatness score 2 or 3of the EU classification system for light lambs) while nine (12.3%), which showed an insufficient fatness (score 1), were classified as 2nd quality. These accounted for 14.3% of carcasses classified as category B and were 80.0% of those placed in category A. On the contrary, all the carcasses classified in category C were of 1st quality. No carcass showed an excessive degree of adiposity (score 4).

Average carcass weight of lambs slaughtered at Christmas tended to be higher than that of lambs slaughtered at Easter, even differences were not significant ($P=0.10$). Respectively 3, 14 and 19 carcasses were included in EU category A, B and C at Christmas while 2, 21 and 14 were included in the same categories at Easter, without significant differences at a chi-square analysis within the categories. Also mean carcasses weight within the categories, as average fatness degree, did not differ significantly between the two slaughter sessions. So, the carcass quality of lambs born and bred in autumn, when pasture is available for the sheep, was slightly different from those bred in winter which mothers were stall-fed meadow hay and concentrate supplementary foods.

3.2. Meat quality traits

Meat characteristics related to the rearing season are shown in Table 2. Even if all the carcasses had a pink or pale pink colour of meat at the visual colour assessment, the most significant differences observed concerned colour instrumental measurements. Meat lightness L* was significantly higher in lambs reared in winter ($P=0.02$) than those reared in autumn while their Chroma C* was comparatively lower ($P=0.01$). Meat colour, besides live weight, depends on

Table 1
Carcasses distribution and weight of suckling light-lambs according to the rearing season (mean values).

Parameters		General mean	Rearing season		*P*	M.S.E
			Autumn	Winter		
Reference carcass number	*n* (%)	73 (100)	36	37	–	
Carcasses distribution into the EU categories						
A (≤7 kg)	*n* (%)	5 (6.8)	3	2	0.62	*
B (7.1≤10 kg)	*n* (%)	35 (47.9)	14	21	0.13	*
C (10.1≤13 kg)	*n* (%)	33 (45.2)	19	14	0.20	*
Reference carcass weight	kg	9.7	10.03	9.37	0.10	0.20
Carcasses weight into the EU categories						
A (≤7 kg)	kg	6.1	6.23	5.97	0.61	0.23
B (7.1≤10 kg)	kg	8.8	9.06	8.61	0.12	0.14
C (10.1≤13 kg)	kg	11.2	11.34	10.99	0.25	0.15
Fatness degree		2.18	2.26	2.10	0.22	0.07

*compared within the same category between the 2 different rearing seasons using a chi-square test.

age, exercise and nutrition (Sañudo, Santolaria, María, Osorio & Sierra, 1996). At similar age, average carcass weight of lambs slaughtered at Easter tended to be lower than that of lambs slaughtered at Christmas ($P=0.10$), possibly influencing their muscle colour. Teixeira et al. (2005) evidenced a reduction in lightness with the increasing live weight. This effect of live weight on colour instrumental measurements was also found by Vergara, Molina and Gallego (1999), Beriain, Horcada, Purroy, Lizado, Chasco and Mendizabal (2000) and Fogarty, Hopkins and Vande Ven (2000).

Another factor which influence muscle colour is the pH (Priolo, Micol & Agabriel, 2001), which value, nearly significant after 45 min in the present trial, became significantly higher after 24 h in lambs reared in winter, even within a normal range as absolute value. The lambs reared in the two seasons displayed on the contrary a similar drop in pH. Teixeira et al. (2005), studying lambs slaughtered at different live weights, could evidence ultimate pH significantly higher in heavier lambs than lighters. Also Sañudo et al. (1996) and Beriain et al. (2000), working with lambs from Spanish breeds observed higher pH values on the heavier carcasses, but Vergara et al. (1999) and Tejeda, Peña and Andrés (2008) did not find effects of slaughter weight on 24 h pH. The differences in ultimate pH we found in the present trial could then be ascribed to a variation in glycogen content of muscles, probably lower in lighter lambs, as stated by Sañudo et al. (1996). These lambs, reared in winter, also showed a drip loss significantly lower ($P<0.01$). Vergara et al. (1999) evidenced lower values of water holding capacity (WHC) with increasing slaughter weight. Similar results were referred by Hawkins, Kemp, Ely, Fox, Moody and Vimini (1985) which observed a progressive loss of WHC as carcass weight increased. Sañudo et al. (1996) on the contrary did not evidence any effect of live weight on WHC. As absolute values, cooking losses were similar to those found by Miguélez, Zumalacàrregui, Osorio, Figueira, Fonseca and Mateo (2008) and no differences could be evidenced between the lambs slaughtered in the 2 seasons. On the contrary, the intramuscular fat content was significantly higher ($P=0.04$) in the lambs born and bred in autumn, when pasture is available for their dams, than in lambs bred in winter. This effect can be ascribed to the pasture based farming system which generally results in better milk performance characterized by high fat content due to diets rich in fibre (Morand-Fehr, Fedele, Decandia & Le Frileux, 2007).

3.3. Fatty acid composition

Table 3 presents the effects of the rearing season on the fatty acid composition (fatty acid percentage by weight of total fatty acids) of the *L. lumborum* intramuscular fat.

Table 2
Meat quality traits in *M. longissimus lumborum* of Apennine suckling-lambs according to the rearing season (mean values).

		General mean	Rearing season		*P* values	M.S.E.
			Autumn	Winter		
Samples	*n.*	73	36	37	–	–
pH_1	–	6.44	6.38	6.49	0.11	0.035
pHu	–	5.76	5.70^{B}	5.81^{A}	<0.01	0.019
pH_1–pHu	–	0.68	0.68	0.68	0.88	0.033
Colour parameters:	–					
- L*	–	41.95	40.88^{b}	43.00^{a}	0.02	0.44
- Chroma*	–	14.83	15.46	14.22	0.01	0.17
- Hue°	–	17.34	16.91	17.76	0.23	0.35
Drip loss	%	1.66	1.98^{A}	1.34^{B}	<0.01	0.05
Cooking loss	%	24.01	23.21	24.80	0.15	0.54
Meat composition[(a)]:						
- moisture	%	75.64	75.48	75.80	0.67	0.38
- protein ($N\times6{,}25$)	%	20.62	20.45	20.78	0.59	0.31
- lipids	%	2.41	2.67^{a}	2.16^{b}	0.04	0.12
- ash	%	1.33	1.40	1.25	0.20	0.03

Means in the same row with different lower-case letters are significantly different: a *vs* b: $P\leq0.05$; A *vs* B: $P\leq0.01$. [(a)] (% fresh weight basis).

The fatty acid profile of lambs reared in autumn and slaughtered at Christmas was clearly different from those reared during winter and slaughtered at Easter.

Particularly, the lauric acid (C12:0) was significantly ($P=0.04$) higher in the intramuscular fat from lambs slaughtered at Christmas. The intramuscular fatty acid composition of animals suckling their mothers' milk is closely related to the fatty acid composition of ewe milk which is rich of medium-chain and saturated fatty acids (C12:0, C14:0 and C16:0) (Velasco, Cañeque, Lauzurica, Pérez & Huidobro, 2004). Nuernberg, Fischer, Nuernberg, Ender and Dannenberger (2008) reported that the milk content of C12:0 increases in grazing animals. Moreover, the difference found in our research should probably be related to a greater milk supply from ewes reared at pasture in autumn. No differences were however evident concerning the total SFA muscular proportion in lambs slaughtered at Christmas or at Easter.

A higher concentration of heptadecanoic acid (C17:0) was conversely present in *L. lumborum* muscle of the lambs slaughtered at Easter. Since the rumen synthesised short-chain volatile fatty acids, including propionic acid, which is a precursor of odd-chain carbon atom fatty acids (Oriani, Maiorano, Filetti, Di Cesare, Manchisi & Salvatori, 2005), this result can be ascribed to a likely greater consumption of concentrate these lambs, born and bred in winter, normally achieve, as a consequence of a reduction of ewes milk yield and milk fat due to indoor rearing system in winter (Morand-Fehr et al., 2007).

The greater concentration of oleic acid (C18:1 *n*-9) found in these lambs ($P<0.01$) should also be ascribed to their feeding system. Also Scerra, Caparra, Foti, Galorafo, Sinatra and Scerra (2007) reported that oleic acid is higher in intramuscular fat from lambs which ewes were stall-fed compared to those which dams were pasture-fed. Furthermore, the greater consumption of concentrate the lambs bred in winter normally achieve may have influenced the proportion of monounsaturated fatty acids in corporal lipids as a result of a greater

Table 3
Fatty acid composition (%) of intramuscular fat of *M. longissimus lumborum* of Apennine suckling-lambs according to the rearing season (mean values).

	General mean	Rearing season		*P* values	M.S.E.
		Autumn	Winter		
Samples (*n.*)	73	36	37	–	–
C12:0	0.76	0.84^{a}	0.69^{b}	0.036	0.061
C14:0	6.12	6.32	5.94	0.183	0.297
C15:0	0.66	0.63	0.69	0.185	0.026
C16:0	24.02	23.45	24.56	0.201	0.465
C16:1	1.78	1.75	1.80	0.692	0.078
C17:0	1.12	1.03^{B}	1.20^{A}	0.001	0.032
C18:0	12.68	12.38	12.96	0.167	0.296
C18:1 *trans tot.*	2.29	2.56	2.03	0.171	0.230
C18:1 *n-9*	30.87	29.52^{B}	32.19^{A}	0.001	0.591
C18:1 *n-7*	1.25	1.21	1.28	0.326	0.046
C18:2 *n-6*	9.33	9.82	8.86	0.223	0.448
C18:3 *n-3*	1.88	2.57^{A}	1.21^{B}	<0.001	0.154
C18:2 *cis 9 trans11 (CLA)*	0.82	1.10^{A}	0.56^{B}	<0.001	0.070
C20:3 *n-6*	0.32	0.31	0.32	0.820	0.024
C20:4 *n-6*	3.55	3.52	3.58	0.845	0.210
C20:5 *n-3*	1.12	1.45^{A}	0.81^{B}	<0.001	0.086
C22:5 *n-3*	1.42	1.53	1.32	0.211	0.096
SFA	45.36	44.65	46.04	0.355	0.676
MUFA	36.19	35.05^{B}	37.31^{A}	0.009	0.643
PUFA	18.46	20.32^{A}	16.65^{B}	0.010	0.896
MUFA/SFA	0.80	0.79	0.82	0.177	0.019
PUFA/SFA	0.42	0.47^{a}	0.37^{b}	0.015	0.026
Total *n*-3	4.43	5.56^{A}	3.34^{B}	<0.001	0.292
Total *n*-6	13.20	13.66	12.76	0.425	0.634
n-6/*n*-3	3.30	2.60^{B}	3.98^{A}	<0.001	0.138

Means in the same row with different lower-case letters are significantly different: a *vs* b: $P\leq0.05$; A *vs* B: $P\leq0.01$.

proportion of propionic acid in the rumen which shortens the stay of feed, decreasing thus biohydrogenation of unsaturated fatty acids (Petrova, Banskalieva & Dimov, 1994).

While the MUFA had a higher concentration in the meat of lambs slaughtered at Easter (37.31% vs 35.05%, $P<0.01$), the PUFA had an opposite trend (16.65% vs 20.32%, $P=0.01$). Particularly, the proportion of linolenic (C18:3), eicosapentaenoic (EPA, C20:5) and rumenic (C18:2 cis-9 trans-11) acids was significantly higher ($P<0.001$) in the muscle of lambs slaughtered at Christmas, leading them to a more favourable PUFA/SFA ratio. Moreover, their highest concentration of *n*-3 fatty acids resulted in a significant reduction of *n*-6/*n*-3 ratio (2.60 vs 3.98, $P<0.001$).

Biondi, Valvo, Di Gloria, Scinardo Tenghi, Galorafo and Priolo (2008) demonstrated that a diet based exclusively on green herbage, compared to a diet based on concentrate or a total mixed ration, increases the amount of both conjugated linoleic acid (CLA) and *n*-3 fatty acids in ewe milk. Particularly, linolenic acid amount is high in herbage even if its content depends on the season and herbage varieties and, although it is rapidly and extensively biohydrogenated in the rumen, its higher availability from fresh herbage can increase its content in milk (Biondi et al., 2008). Also Valvo et al. (2005) and Atti, Rouissi and Othmane (2006) observed a higher content of linolenic acid in milk from ewes raised on pasture compared to stall-fed animals. Interestingly, Scerra et al. (2007) found that the proportion of PUFA was higher in muscular fat of lambs which mothers had access to pasture than lambs from ewes of a stall-fed group. Particularly, the level of linolenic acid (C18:3 *n*-3) was twofold higher in lambs from ewes of the pasture-fed group, related with a significantly higher level of this fatty acid in the milk compared to the milk from stall-fed ewes. So, the higher proportion of linolenic acid and generally *n*-3 acids observed in the lambs reared in autumn in our trial should be related to the typical practice to turn their dams out to pasture during this season. Due to higher intake of linolenic acid, the proportion eicosapentaenoic acid (EPA, C20:5), that is derived from it, was also higher in the intramuscular fat of these lambs.

A greater presence of CLA in the ewes' milk may also be the cause of its higher concentration in the intramuscular fat of the carcasses of lambs reared in autumn. The higher content of rumenic acid in milk from ewes grazing pasture is in agreement with literature. Green forage fed ewes showed from two times (Valvo et al., 2005) to four times (Atti et al., 2006) higher milk CLA contents compared to stall-fed animals. Particularly, the concentration of CLA in milk from grazing sheep ranges from 0.5–1% to 2.5–3.0% and probably depends on the concentration of PUFA of forage species (Cabiddu et al., 2003; Cabiddu, Decandia, Addis, Piredda, Pirisi & Molle, 2005). Some authors have recently hypothesized that rumenic acid could be an intermediate of linolenic acid biohydrogenation. (Biondi et al., 2008).

Therefore, a great influence of the rearing season has to be considered when fatty acid composition is concerned.

4. Conclusions

The semi-extensive farming system practiced with Apennine breed in Central Italy to produce a traditional suckling lamb, slaughtered around Easter or Christmas at about 60 days of age, has to consider the effects of the rearing season on meat quality, due to the differences in the availability of feeding resources.

Particularly the meat of lambs slaughtered at Christmas has a higher fat content, a greater PUFA concentration, a more favourable *n*-6/*n*-3 ratio, and a higher CLA content than those reared in winter (slaughtered at Easter), as a result of the traditional feeding system which provide that lambs born and reared in autumn receive milk from ewes permanently pastured while those reared in winter are suckled by ewes permanently stall-fed.

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