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# Growth rate, meat quality and fatty acids composition of "Agnello di Sardegna" PGI light lambs

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**Abstract**

The work aims to fill the knowledge gap on performance and meat quality of "Agnello di Sardegna" PGI light lambs. To this end fourteen male lambs, homogeneous for age and litter size and consisting of seven pure Sarda (S X S) and seven crossbred Ile de France x Sarda (IF X S) lambs were compared for growth rate, dressing-out percent, chemical composition, fatty acids (FA) composition of Longissimus lumborum muscle and some nutritional indexes. Lambs suckled and followed their mothers at pasture until slaughtering at17±3 kg Live Weight and 50±1 days old, (means±s.d). The SXS lambs showed higher content of some healthy fatty acids (EPA) and better values of some nutritional indexes (Thrombogenic and Ipo-ipercholesterolemic index). The effect of litter size was more pronounced than sire effect, affecting both chemical and FA composition of light lambs. The single lambs showed higher branched chain fatty acids, linoleic and linolenic acid, CLA and other healthy fatty acids (DPA, DHA, omega 3 polyunsatured fatty acids) content. Overall, the value of nutritional indexes highlighted the high nutritional quality of light lamb meat. The results do not seem to justify the use of specialized meat breed as Ile de France for light lamb production, the short period between birth and slaughter not allowing the crossbred lambs to show their greater potential for muscle development. The high CLA content together with fatty acids considered beneficial for consumer health (DPA, DHA) in meat of single light lambs is a result to take into account in a meat production system aimed at high quality.

**Keywords:** Sarda lambs; litter size; meat composition; CLA; Branched chain fatty acids (BCFA); Nutritional quality

## Introduction

The Italian sheep population, numbering about 7.000.000 heads [1], consists mainly of breeds specialized in milk production, such as Sarda and Comisana (the most numerous breeds), Pinzirita, Valle del Belice and Massese (of local importance) [2]. The Sarda breed, with more than 3.000.000 heads [1], is reared mainly in the island of Sardinia, where sheep livestock system still represents the main activity in many rural areas [3].

The Sarda sheep production system is based on natural pasturing, with lambing season mainly in November–December for adult ewes and in February–March for yearlings, to maximize the amount of sheep milk directed towards the cheese production. The Sarda lambs are poorly suited genetically to produce heavy carcasses [2] and are traditionally slaughtered between 30 and 40 days of age (suckling lambs), in conjunction with Christmas and Easter when their meat is traditionally consumed. Sarda suckling lambs is a traditional meat product, and accounts for about 42% of the total Italian production [4], with about 1.7 million of lambs slaughtered every year [5]. Until now, for Sardinian sheep farmers, lamb meat has been a secondary product, although important, respect to the milk production, representing about the 30% of the gross saleable product, [4]. The decline in profitability of sheep milk prices, in the recent past, induced the sheep livestock sector to re-evaluate lamb meat as source of income. In this perspective, the farmers are trying to implement a diversification of meat production, which can include, besides the traditional suckling lamb, the production of light and heavy lamb, considering also that these products are actually granted by the European Union label "Agnello di Sardegna" (Protected Geographical Indication CE No 138/01). The product "light lamb", belonging to the

Sarda breed or from cross-breeding of Sarda ewes with highly specialized meat breeds (F1) and fed mainly with mother's milk, is sacrificed at cold carcass weight between 7 and 10 kg. This product could allow a higher productivity and give more flexibility in production systems, taking into account that, according with [6], the production of slightly heavier carcasses and slaughter weight should not compromise the quality of products. The cross-breeding with Ile de France and Berrichon du Cher, to improve both productive performance and meat quality [7] is not widespread in Sardinia, although the F1 lambs have higher growth rates and can be sacrificed at heavier weights than pure Sarda breed lambs, as shown in previous studies [8-10]. Since the value of a food cannot be separated from its characterization regarding, in particular, nutritional and nutraceutical properties, the attention of researchers on Sarda suckling lamb meat quality has markedly raised up [3,11,12]. To date several studies have concerned the meat quality of suckling lambs but information for the characterization of "Agnello di Sardegna" PGI light lambs is lacking The aim of this work was to fill this knowledge gap, evaluating the effects of litter size and sire breed (Sarda or Ile de France) on performances, meat quality and nutritional parameters (chemical and fatty acid composition) of light lambs.

## Materials and methods

The experiment was carried out at the Bonassai experimental farm (Olmedo, Sardinia, Italy 40°N, 8°E, 32 m a.s.l.) of Agris, Livestock Production and Animal Product Divisions. It was conducted in compliance with the principles and specific guidelines on animal care and welfare as required by Italian law (Gazzetta Ufficiale, DL no. 116, January 27, 1992).

### Animals and Management

Fourteen male lambs, homogeneous for age and litter size were divided into two groups consisting of seven pure Sarda (S X S) and seven crossbred Ile de France x Sarda (IF X S) lambs. The lambs, together with their dams, managed as a group, rotationally grazed 5.5 ha of perennial or self-reseeding pastures from 15 days before pregnancy to lamb slaughtering. The adult ewes were supplemented with ryegrass hay and a commercial concentrate (0.3 kg/head day and 0.4 kg/head day, respectively) until lambing; after the ewes received alfalfa hay (0.5 kg/head day) and a commercial concentrate (0.5 kg/head day). During the experimental period, as traditionally in Sardinia, lambs were naturally suckled, grazed with their dams and were managed in one flock under identical conditions, without any discernible differences in nutrition or management.

### Measurements and Samplings

The lambs were weighted at birth and every week until slaughter at the same time of day (0830 Central European Time, CET) to minimize the effects of diurnal variations in feed intake. Average daily gain (ADG) was then calculated as the coefficient of the linear regression of live weight on time. At the foreseen slaughter age (50±1 days old and 17±3 kg live weight, mean±st. dev), the lambs were transported to a commercial abattoir, authorized according to EU legislation, weighed before sacrifice (LWS) and all slaughtered within 1 h from arrival, to minimize pre-slaughter stress. The chilled carcass weight (CCW) after 24 h of cooling at 4°C was determined. The dressing-out percent was calculated by the following formula:

dressing-out percent = (CCW/LWS) × 100.

The pH value of Longissimus lumborum muscles (LL) muscle was measured 24 h post-mortem (ultimate pH, pHu) between the 1st and 2nd lumbar vertebra, using a Eutech pH 600 pH meter with a penetrating probe and a temperature compensator (Eutech Instruments Pte Ltd, Singapore/Oakton Instruments, USA). In the abbatoir, at 24 h post-mortem, carcasses were sliced at the 1st and 2nd rib of LL muscle and colour coordinates were measured on the exposed cut surface, after 1 hour of air exposure, with a Chroma Meter CR-400 colorimeter (KONICA MINOLTA Sensing Inc., Japan) according to the CIE L* a* b* system and standard illuminant C. Two locations were randomly selected to have a representative reading of surface colour and the measurements were averaged [13]. Colour measurements were made directly on the meat surface without overwrap film [14]. The lightness (L*), redness (a*) and yellowness (b*) were recorded Muscle LL was collected from 1st to 5th lumbar vertebra for chemical analysis and intramuscular fatty acid (FA) composition. Meat, trimmed to remove residual adipose tissue and the epimysium, grounded and homogenized using a meat mincer, has been divided into homogeneous samples of 50 g each, vacuum-packaged and stored at -20°C until analysis. Before analysis, the samples were thawed gradually at +4°C for 12h. The milk yield of suckling ewes was estimated as [15].

### Chemical analysis and fatty acid composition

L. lumborum muscle samples were analyzed for dry matter content (DM), intramuscular fat (imf), protein (cp) and ash content using AOAC official methods 950.46, 960.39, 981.10, 900.02, respectively [16]. Muscle lipids were extracted by means of a hexane/2-propanol solution (3:2 v/v), according to Hara and Radin method [17]. Solvent was removed under vacuum on a rotary evaporator at 37°C. Lipid content was determined, gravimetrically, after total solvent evaporation and expressed as g/100g of meat. The extracted lipids (60 mg) were subjected to acid trans-esterification to obtain fatty acids methyl esters (FAMEs) [18]. Gas chromatographic separation of FAMEs was carried out with a VARIAN 3900 GC on a Supelco SP 2560 capillary column (100 m length, 0.25 mm inner diameter, 0.2 µm film thickness). Individual FAMEs were identified by comparison with a standard mixture of 37 components (Matreya Inc., Pleasant Gap PA, USA). Conjugated linoleic acid (CLA) standards (CLA 9c 11t; CLA 10t 12c; CLA 9c 11c; CLA 9t 11t, Matreya) and published isomeric profiles [19] were used to identify the CLA isomers. The quantitative measurement of each fatty acid methyl ester (FAME) was performed with a calibration curve using the internal standards Me-C9:0 (to quantify C8:0÷C10:0), Me-C13:0 (to quantify C11:0÷C17:0), and Me-C19:0 (to quantify C18:0÷C26:0). The concentration of each


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internal standard added to the fat sample was 170 mg/g of fat. The contents of total cholesterol in the meat samples were determined by the methods proposed by [20] and [21].

Before the analyses, data on the fatty acid composition were processed to compute the contents of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), ω3-PUFA [C18:3 9c 12c 15c (linolenic acid ALA), C20:5 (EPA), C22:5 (DPA) and C22:6 (DHA)] and ω6-PUFA [(C18:2 9c 12c (linoleic acid LA), C20:3, C20:4 (arachidonic acid)]. Moreover, the following ratios were calculated: ω6/ω3, P/S (PUFA/SFA), as well as the LA/ALA ratio, considering its interest in infant nutrition.

Moreover, The atherogenic index (AI) and Thrombogenic index (TI) were calculated according to the formulas proposed by [23].

AI = (C12:0+4*C14:0+C16:0)/(MUFA+ (ω3-PUFA + ω6-PUFA)

TI = (C14:0+C16:0+C18:0)/ [(0.5*ω6) + (0.5*MUFA)+ (3*ω3)+ (ω3/ω6)]

The Ipo-ipercholesterolemic index (HH) was calculated according to the following formula suggested by [6]: HH = (C18:1 9c + C18:2 9c 1c + C18:3 9c, 12c, 15c + C20:4 +EPA + DPA +DHA)/ (C14:0 + C16:0)

### Statistical analysis

Data of birth and slaughter weights, growth rate, performances at slaughter (dressing-out percent and pHu), meat color parameters, meat chemical composition, fatty acids content of intramuscular fat of L. lumborum of light lambs, nutritional indexes values and ewes milk yield were analysed using a bi-factorial model with sire effect and litter size as fixed effects. The lm procedure of R software version 3.3.2 (The R Development Core Team, 2016), was exploited to develop the model. Differences between treatments were determined by F tests. Tukey's multiple comparison test was applied as appropriate to evaluate pairwise comparisons between treatment group means. Treatment differences with a P-value less than or equal to 0.05 were considered as significantly different, unless indicated otherwise.

## Results

### Growth rate and performance at slaughter

Since the interaction between litter size and sire effect was never significant, the results will not be shown hereafter. The effects of genotype and litter size on birth weight, slaughter weight and on average daily gain (ADG) during experimental period are shown in Table 1.

**Table 1:** Effect of litter size on birth weight, weight at slaughter, average daily gain (ADG), amount of suckled milk, dressing-out percent, ultimate pH meat and colorimetric parameters (least squares means ± SE) of experimental lambs.

| | Single | Twins | Sarda x Ile de France | Sarda X Sarda | Litter size effect (P value*) | Sire effect (P value*) |
|---|---|---|---|---|---|---|
| Birth weight (kg) | 4.14±0.22 | 3.96±0.19 | 4.43±0.21 a | 3.67±0.20 b | 0.55 | 0.03 |
| Slaughter weight (kg) | 18.9±1.2 | 15.6±1.05 | 18.6±1.15 | 15.8±1.10 | 0.07 | 0.11 |
| ADG (kg/day) | 0.299±0.02 a | 0.229±0.02 b | 0.264±0.02 | 0.265±0.02 | 0.03 | 0.96 |
| Suckled milk (ml/animal day) | 1491±96.8 a | 1173±83.3 b | 1329±91.7 | 1335±87.9 | 0.03 | 0.96 |
| Cold Dressing-out percent (%) | 62.5±2.4 | 55.7±2.05 | 61.8±2.25 | 56.3±2.16 | 0.06 | 0.11 |
| pH 24 h.(n°) | 5.72±0.04 | 5.79±0.04 | 5.76±0.04 | 5.75±0.04 | 0.21 | 0.81 |
| L* (n°) | 37.0±0.98 | 38.7±0.84 | 37.9±0.93 | 37.8±0.89 | 0.24 | 0.98 |
| a*(n°) | 17.5±0.84 | 16.5±0.72 | 17.3±0.80 | 16.7±0.76 | 0.62 | 0.39 |
| b*(n°) | 5.0±0.45 | 5.3±0.39 | 4.79±0.43 | 5.50±0.41 | 0.63 | 0.26 |

Means in the same row within sire effect or litter size with no superscript letters after them are not significantly different (P>0.05);
*: P values for the effect tested.

The birth weight was affected by sire effect, with IF x S lambs heavier at birth than purebred ones. The litter size did not affect the birth weight of lambs. The ADG was influenced only by litter size, and single lambs showed higher growth rate than twins (Table 1). The performances at slaughter of experimental lambs did not show significant differences, despite the dressing-out percent tended (P=0.06) to be higher in single lambs than in twins. The pH values, measured 24 h after slaughter, and the colorimetric parameters were unaffected by sire effect and litter size.

### Chemical composition and fatty acid content

The chemical composition of L. lumborum muscle from experimental light lambs is shown in Table 2. Sire effect did not affect chemical composition and cholesterol content whereas litter size affected the DM of meat, higher in single lambs than in twins. The fatty acid profile of L. lumborum intramuscular fat (expressed as a proportion by weight of total fatty acid methyl esters) is reported in Table 2. The main fatty acid of intramuscular fat of light lambs was oleic acid (C18:1 9c) followed by palmitic (C16:0), stearic (C18:0) and myristic (C14:0). The litter size showed a greater influence on fatty acid composition than sire effect. The latter affected the content of some branched chain fatty acids (BCFA, C17:0i and C17:0ai), SFA, some polyinsatured fatty acids (C20:4, C20:5), and some nutritional indexes (TI, HH


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and LA/ALA ratio) (Table 2). The litter size affected some BCFA, LA and ALA content, CLA 9c11t, some derivatives of ALA (DPA and DHA), MUFA and PUFA, n-3 and n-6 fatty acids, TI and HH (Table 2).

**Table 2:** Meat chemical composition and fatty acids composition (% of total fatty acid methyl esters weight) of intramuscular fat of experimental lambs (least squares means ± SE.).

| | Single | Twins | Sarda x Ile de France | Sarda X Sarda | Litter size effect (P value*) | Sire effect (P value*) |
|---|---|---|---|---|---|---|
| Dry matter (DM, % of meat) | 25.3±0.29 a | 23.7±0.27 b | 24.7±0.27 | 24.3±0.29 | 0.002 | 0.38 |
| Ash (%DM) | 1.23±0.02 | 1.21±0.02 | 1.22±0.02 | 1.22±0.02 | 0.63 | 0.88 |
| Intramuscular fat (IMF, %DM) | 2.01±0.44 | 1.63±0.42 | 2.04±0.42 | 1.59±0.44 | 0.57 | 0.5 |
| Proteins (CP, %DM) | 21.1±0.15 | 20.8±0.14 | 20.8±0.14 | 21.2±0.15 | 0.29 | 0.12 |
| Cholesterol (mg/kg) | 778±84.8 | 797±52.3 | 803±68.0 | 772±65.4 | 0.86 | 0.12 |
| C12:0 | 0.47±0.06 | 0.63±0.06 | 0.53±0.06 | 0.57±0.06 | 0.07 | 0.65 |
| C14:0 | 5.2±0.24 | 4.9±0.19 | 5.26±0.21 | 4.81±0.21 | 0.31 | 0.16 |
| C16:0 | 20.7±0.48 a | 19.2±0.38 b | 20.5±0.42 | 19.4±0.43 | 0.03 | 0.09 |
| C14:0i | 0.04±0.003 | 0.04±0.002 | 0.04±0.002 | 0.04±0.002 | 0.41 | 0.49 |
| C15:0i | 0.13±0.005 a | 0.11±0.004 b | 0.13±0.005 | 0.11±0.005 | 0.01 | 0.09 |
| C15:0ai | 0.17±0.01 | 0.18±0.01 | 0.18±0.01 | 0.17±0.01 | 0.54 | 0.51 |
| C16:0i | 0.22±0.01 a | 0.19±0.01 b | 0.22±0.01 | 0.19±0.01 | 0.02 | 0.09 |
| C17:0i | 0.64±0.02 | 0.65±0.01 | 0.68±0.01 a | 0.61±0.01 b | 0.54 | 0.01 |
| C17:0ai | 0.53±0.03 a | 0.43±0.02 b | 0.53±0.03 a | 0.44±0.03 b | 0.03 | 0.04 |
| C18:0 | 11.3±0.30 | 11.8±0.24 | 11.4±0.27 | 11.6±0.27 | 0.24 | 0.65 |
| C18:1 9t | 0.22±0.01 | 0.20±0.01 | 0.21±0.01 | 0.21±0.01 | 0.19 | 0.95 |
| C18:1 9c | 30.0±1.46 | 26.1±1.17 | 29.0±1.29 | 27.1±1.32 | 0.07 | 0.31 |
| C18:2 9c,12c (LA) | 7.45±0.92 b | 10.04±0.74 a | 7.55±0.81 | 9.93±0.83 | 0.05 | 0.07 |
| C18:3 9c,12c,15c (ALA) | 1.96±0.08 b | 2.22±0.07 a | 2.08±0.07 | 2.10±0.07 | 0.04 | 0.87 |
| CLA 9c,11t (VA) | 1.13±0.04 a | 0.94±0.03 b | 1.05±0.04 | 1.02±0.04 | 0.006 | 0.58 |
| C20:4 5c,8c,11c,14c | 2.41±0.41 b | 3.89±0.32 a | 2.54±0.36 b | 3.76±0.37 a | 0.02 | 0.04 |
| C20:5 (EPA) | 0.36±0.04 b | 0.63±0.03 a | 0.46±0.04 b | 0.53±0.03 a | 0.18 | <0.001 |
| C22:5 (DPA) | 1.15±0.16 b | 1.81±0.13 a | 1.29±0.14 | 1.66±0.15 | 0.01 | 0.1 |
| C22:6 (DHA) | 0.57±0.09 b | 0.87±0.07 a | 0.62±0.08 | 0.83±0.08 | 0.02 | 0.09 |
| SFA | 42.8±0.41 | 42.5±0.32 | 43.2±0.36 a | 42.0±0.37 b | 0.6 | 0.04 |
| MUFA | 40.1±1.51 a | 35.2±1.21 b | 39.1±1.34 | 36.2±1.37 | 0.03 | 0.16 |
| PUFA | 17.1±1.5 b | 22.3±1.2 a | 17.6±1.32 b | 21.8±1.36 a | 0.02 | 0.05 |
| UFA | 57.2±0.41 | 57.5±0.32 | 56.8±0.36 b | 58.0±0.37 a | 0.6 | 0.04 |
| PUFA/SFA | 0.44±0.04 | 0.50±0.04 | 0.42±0.04 | 0.52±0.04 | 0.26 | 0.11 |
| ω3-PUFA | 4.5±0.28 b | 5.9±0.2 a | 4.92±0.25 | 5.52±0.25 | 0.003 | 0.12 |
| ω6-PUFA | 10.5±1.34 b | 14.6±1.07 a | 10.7±1.19 | 14.3±1.22 | 0.04 | 0.06 |
| ω6/ω3 | 2.27±0.18 | 2.46±0.14 | 2.15±0.16 | 2.58±0.16 | 0.42 | 0.09 |
| AI | 0.73±0.03 | 0.68±0.02 | 0.74±0.02 | 0.68±0.02 | 0.2 | 0.08 |
| TI | 0.96±0.03 a | 0.84±0.02 b | 0.94±0.02 a | 0.86±0.02 b | 0.006 | 0.05 |
| HH | 1.70±0.07 b | 1.91±0.06 a | 1.70±0.06 b | 1.91±0.06 a | 0.04 | 0.04 |
| LA/ALA | 3.74±0.37 | 4.55±0.30 | 3.61±0.33 b | 4.68±0.33 a | 0.11 | 0.04 |

VA: vaccenic acid; LA: linoleic acid; ALA: linolenic acid; EPA: eicosapentaenoicacid; DPA: docosapentaenoic acid; DHA: docosahexaenoic acid; SFA: Saturated Fatty Acids; MUFA: Monounsaturated Fatty Acids; PUFA: Polyunsaturated Fatty Acids; UFA: Unsaturated Fatty Acids;
ω3: C18:3 9c 12c 15c (ALA), C20:5 (EPA), C22:5 (DPA) and C22:6 (DHA)
ω6: C18:2 9c 12c (LA), C20:3, C20:4 (arachidonic acid).


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AI = (C12:0+4*C14:0+C16:0)/(MUFA+ (ω3-PUFA + ω6-PUFA).
TI = (C14:0+C16:0+C18:0)/[(0.5*ω6)+(0.5*MUFA)+(3*ω3)+(ω3/ω6)]
HH=(C18:1 9c + C18:2 9c 1c + C18:3 9c, 12c, 15c + C20:4 +EPA + DPA +DHA)/(C14:0 + C16:0)
Means in the same row within sire effect or litter size with no superscript letters after them are not significantly different (P>0.05);

*: P values for the effect tested.

## Discussion

The higher birth weight of IF x S lambs than purebred (Table 1) is in agreement with [24-26] and [27]. The ADG, as expected, was influenced by litter size while the sire effect did not play a significant role, contrary to what found in [28] and [29]. The lambs have been sacrificed at 50±0.1 days old (means±s.e) likely before the greater growth potential of the sire breed in IF x S lambs could extrinsic. As reported in Table 1 the performances at slaughter of light lambs did not show significant differences, except for the dressing-out percent, that tended (P=0.06) to be slightly higher in single lambs, mirroring the result of slaughter weight (higher in single lambs, P=0.07), being probably a consequence. The lack of significance of sire effect on pHu and dressing-out percent, in disagreement with [30,31] and [28] (as well as the results of performances ante mortem previous reported) appears to be due to the age and weight at slaughter of experimental lambs, since the better attitude to meat production of IF X S lambs occurs at higher weights and greater slaughtering ages than those recorded in this work.

The pHu values fell within the accepted quality range for all the animals [32] and were in line with [5] in Sarda suckling lambs, with [33] in Portuguese lamb of Bragançana and Mirandesa breeds as well as in Spanish suckling lamb of Manchego [33] and Churra [34]. The values of meat colorimetric parameters, unaffected by treatments (Table 1), differed from suckling lambs in [3], confirming that, within breed, color parameters are influenced by live weight. In particular, as slaughter weight and age increased compared to suckling lambs, meat lightness decreased and the redness, together with yellowness index (a* and b*) increased. The higher a* index depends on an increase of the myoglobin concentration in the meat of light lambs and the higher b* index is probably due to the xanthophylls and carotenes content in the grazed pasture, considering that light lambs, thanks to their age, grazed more than suckling lambs. Meat chemical composition of light lambs (Table 2) is comparable to that reported by [5], [12] and [3] for Sarda suckling lambs, and to those of other breeds (Lacha, Rasa Aragonesa, Barbaresca, Churra, Grazalema Merino and Churra Lebrijana) reared and slaughtered in similar conditions [34-37].

Except for DM, the meat chemical composition was not affected by treatments. The higher DM of meat in single lambs (P=0.002, Table 2) can occur as a result of total lipid content in the muscle, numerically higher in single lambs, although not statistically significant, being these traits directly related [38]. The intramuscular fat content of twin and Sarda lambs' meat was lower than 2-3%, threshold value to ensure good organoleptic qualities [33]. Total cholesterol content was not affected by treatments and ranged from 772 mg/kg to 803 mg/kg muscle (Table 2), in line with [12] in Sarda suckling lambs, and with [39] in Texel x Polwarth and Texel x Corriedale crossbred lambs.

The fatty acid profile (Table 1) of lamb meat is typical of suckling lambs, considered as functional monogastrics, and linked to the fatty acid composition of maternal milk [40- 45]. Milk digestion occurs in the abomasum and the dietary fatty acid profile is not modified by the ruminal biohydrogenation. The main fatty acids were oleic acid (C18:1 9c) followed by palmitic (C16:0) and stearic (C18:0). Whereas palmitic acid is thought to increase blood cholesterol level [46], oleic acid can help to reduce both plasma cholesterol and triglycerides [47] and stearic acid should not elevate LDL-cholesterol being poorly digested and desaturated to oleic acid [12,4849]. Ruminant products are the major dietary sources of conjugated linolenic acids (CLA), and the C18:2 9c, 11t isomer (rumenic acid, RA) can help to prevent carcino-genesis and atherogenesis [50].

As reported by [42] and [44], RA in meat lambs results from: (1) dam's milk, through the bio-hydrogenation of trans-vaccenic acid (VA) by the action of stearoyl Co-A desaturase (SCD) enzyme in the rumen and in the udder of ewes and subsequent incorporation into milk; (2) endogenous synthesis in lamb muscle by way of the SCD enzyme. The level of rumenic acid found in this experiment (Table 2) was in line with other studies on suckling lambs [3,36,37]. Whereas sire effect was not significant on RA content, single lambs showed highest level of RA (1.13% versus 0.93%; P=0.006, Table 2). As found by [51] for kids, the difference in RA content could be probably explained by the higher amount of milk suckled by the single respect to twin lambs (P=0.03, Table 1) estimated according to [15]. Moreover, the dam's milk was characterized by a high content of RA (1.63 % FAME) and vaccenic acid (3.71% FAME, data not shown) due to dietary regimen of lactating ewes based on grazing [52-54]. Furthermore, according to [44], the highest amount of RA in L. lumborum of single lambs could be due to an incipient rumen activity, as indirectly demonstrated by the content of some branched-chain fatty acid content (C15:0i, C16:0i and C17:0ai), highest in single lambs (Table 2). BCFAs are synthetized by bacteria as a main component of the bacterial membrane and, hence, are found in ruminant meat because of rumen bacterial activity [55]. An increase in BCFA content may be desirable and, given their potential anti-carcinogenic effects, BCFAs could be considered bioactive compounds [55-57] stated that forage-based diets promote ruminal cellulolytic bacteria proliferation, increasing the outflow of BCFA. The sire effect affected some BCFA content, and IF X S lambs showed higher C17:0i, C17:0ai and C15:0i and C16:0i (P=0.09 for these latter, Table 2). Both for single and IF


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X S lambs, it is reasonable to think that the highest rumen activity, indirectly highlighted by the greater content of some BCFA, is likely due to a greater grazing activity, linked, in turn, to the greater body weight of single and IF X S lambs, as demonstrated by their greater slaughter weight, although not statistically significant (Table 1). Table 2 highlighted that twin lambs had highest level of some long chain polyunsatured fatty acids (LA, ALA, C20:4 arachidonic acid, DPA, DHA, PUFA, ω3 and ω6-PUFA). It should be stated that the difference (not statistically significant, Table 2) in IMF level between single and twins may affect the proportion of individual FA and could lead to misinterpretations [6,32,57-59]. While the triacylglycerol content in intramuscular fat is strongly and positively related with the total fat content and varies from 0.2 to more than 5% [60], the amount of phospholipid in intramuscular fat is relatively constant (0.2-1% of muscle weight [58]), being their proportion strictly controlled in order to maintain membrane properties. As phospholipids are particularly rich in PUFA (whereas triacylglycerols contain much lower amounts of PUFA) at low levels of fat the contribution made by phospholipids and by long chain PUFA is proportionately greater [61,62,45]. The higher content of C20:4, DPA, DHA in twins than single lambs, due to the higher content of their precursor (LA and ALA), determined the greater content of ω6 and ω3-PUFA.

The PUFA/SFA ratio value, not influenced by treatments, was near to 0.45, below which is considered unhealthy because of its hypercholesterolaemic action [63] and in line with previous observations in suckling lamb [3,5,11,37]. The ω6/ω3 ratio, unaffected by treatments, was below 4, the value recommended by [63] and in line with [5,11,36,64] in suckling lambs.

The values of the atherogenic index (AI) and thrombogenic index (TI) were lower than 1, indicating good dietetic characteristics of this meat [23,65]. The lower value of TI in twin and Sarda lambs seems result from their higher ω3 content, although, for Sarda lambs not statistically significant (P=0.12). The ratio hypocholesterolaemic:hypercholesterolaemic (H/H) refers to the ratio of hypocholesterolemic over hypercholesterolemic fatty acids and is related with the specific effects on cholesterol metabolism. Higher HH values are considered more beneficial to human health [66]. HH index was affected by both sire effect and litter size: Sarda pure and twin lambs showed higher value. Many pediatricians recommend the lamb as first meat at baby's weaning because of its presumed lower allergenicity compared with other meats [11]. In infant nutrition the LA/ALA ratio in the diet could play an important role in C20:4 and DHA biosynthesis, considered essentials for normal neural development of the infant [67]. For this reason, the infant diets should have an LA/ALA ratio between 5:1 and 15:1 [11,68]. The LA/ALA ratio was below the recommended value and not different between twin and single lambs, whereas the S X S lambs showed higher value than IF X S lambs, probably due to their higher LA content.

## Conclusions

This work represents a first attempt to fill the lack of knowledge on "Agnello di Sardegna" PGI light lamb, highlighting the high nutritional quality of meat and characterized by nutritional indices values within the recommended limits. The production of the light lamb with a cold carcass weight of 7-10 kg does not seems to justify the use of specialized meat breed, as Ile de France. Indeed, in the short period (50 days) between birth and slaughter, the crossbred lambs fail to show their greater potential for muscle development than purebred ones. The high nutritional quality of intramuscular fat in lamb meat, highlighted by the nutritional indices, is related to the feeding system of dams, based mainly on grazing. The lambing season, occurring in November-December and February-March, allow the suckling ewes to graze the high-quality herbage available for from winter to spring. The very high CLA content in meat of single lambs, in addition to the greater amount of intramuscular fat, respect to twin ones, is a result to take into account in a meat production system aimed at high quality, featured by high CLA levels and better intramuscular fat content.

## Conflict of interest

There is no conflict of interest in this article.

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