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Sustainable Rearing for Kid Meat Production in Southern Italy Marginal Areas: A Comparison among Three Genotypes

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Abstract: Sustainable goat breeding plays an important role in the economy of marginal areas. The present study aimed to compare performances and meat quality traits in kids of a native Apulian genotype (Garganica) in comparison with two Mediterranean breeds (Maltese and Derivata di Siria). Kids suckled dam milk until they were 21 (±2) days old, hence three groups of 12 male kids per each genotype were made. The kids received a pelleted feed ad libitum in addition to dam milk and were slaughtered at 60 days of age. The Maltese kids showed the lowest net cold-dressing percentage, with statistical differences compared to Garganica and Derivata di Siria. Meat obtained from Garganica kids showed a rosy color due to a significantly lower a* index and were also more tender since a lower WBS was recorded in comparison with the other two genotypes. As for the nutritional value of meat, the best n-6/n-3 ratio was found for the Derivata di Siria breed. In conclusion, Garganica kid meat showed the lowest content of SFA and atherogenic index, with potential beneficial effects for human health.

Keywords: kids; Garganica; Maltese; Derivata di Siria; meat quality; fatty acids; biodiversity; sustainability

1. Introduction

Goat breeding plays an important role in the economy of several countries because of their ability to adapt to different climates, management conditions and to regulate their feeding regimens according to the availability of food resources, which may be very poor in harsh geographical areas, where it is difficult to rear other animal species [1]. In the Basilicata region, the pedo-climatic conditions and the rocky and hostile territory of the inland mountain areas prevent the cultivation of food resources for livestock animals reared under semi-intensive or intensive conditions. Moreover, the lack of infrastructures is a severe limitation for farmers. Traditionally, sheep and goat grazing systems are the only possible source of income from livestock in this region. This has led rural populations to preserve the historical and cultural heritage related to local small ruminant breeds, also to avoid biodiversity loss.

To date, there is a growing interest in the nutritional properties and high quality of goat products [2]. Consumers are oriented towards foods of animal origin that are perceived as being healthy and wholesome. Goat-meat acceptability varies widely depending on cultural traditions, age, socioeconomic conditions and family habits that influence the consumer's preference [3,4]. In Italy "capretto" is the main kind of goat meat appreciated by the consumer. This meat has a light or rosy color, with a delicate and wild taste due to kids suckling milk from goats that graze on spontaneous

pastures and scrubs typical of the Mediterranean area [5,6]. The traditional "capretto" is consumed during Easter and Christmas festivities that correspond to the two seasonal kidding times. Kids are typically slaughtered at about 4–7 weeks of age with an average weight that ranges from 10 to 12 kg.

The EU Regulation N. 2018/848 concerning organic production strongly suggests taking into account the genetic value of animal breeds along with longevity, vitality, ability of the animals to adapt to the environment and disease resistance. Preference should be given to native breeds and genetic lines, privileging genetic diversity. As the only form of animal husbandry that is gaining growing interest in the last decade is organic livestock farming, the exploitation of autochthonous breeds has a renewed significance—especially for small ruminant breeders who apply multifunctional agriculture. The concept of integrated agroforestry and silvopastoral systems, based on connections between conventional agriculture with other on-farm services (e.g., tourism, educational activities, social agriculture, etc.) offers rural populations the chance to diversify and increase incomes from their multifunctional farms involved in food production, environmental conservation and on-farm services. In this system, there is the integration of forests, tree plantations and herbaceous crops with grazing small ruminant species.

Genetic and environmental factors are also known to affect meat production and quality in goats [7,8]. As reported by several authors, the feeding system, breed, age and gender are able to influence growth, muscle and fat deposition and, therefore, may affect meat quality in small ruminants [2,3,6,8–13]. In the Basilicata region, the Garganica, Maltese and Derivata di Siria goat breeds are usually reared for milk production, which is processed into traditional cheeses.

The Garganica breed originated in the Gargano promontory in the Apulia region by crossing the autochthonous population of goat with west European goats. This breed shows an exceptional ability to utilize poor pasture that would not otherwise be used. Animals are medium-sized and have black glossy hair with some reddish shade and long twisted horns in both sexes. The average milk production ranges from 200 to 250 L in 210 days; the milk is high in protein (3.5%) and fat (4.8%) [14,15]. Nowadays, the Garganica goat breed is included in the list of Italian endangered breeds maintained by the Italian Department for Environment, Food and Rural Affairs [16]. The Maltese goat has white body with long hair, black head and large drooping ears; this breed has no horns. Milk production is about 350 L with high fat (3.8%) and protein (3.3%) content; prolificacy is high (180%) [17]. The Derivata di Siria is a Sicilian domestic dairy goat which derives from the Damascus goat of Syria. This breed has a peculiar reddish-brown coat and a milk production of ~570 L per lactation. The milk contains 4.11% fat and 3.53% protein [18]. Garganica, Maltese and Derivata di Siria goats are reared also in other regions in Southern Italy (Basilicata, Campania, Calabria).

The aim of the research was to carry out a comparative study on growth performances and meat physical, chemical and fatty acid composition in Garganica kids, an Apulian autochthonous breed, in comparison with two Mediterranean breeds (Maltese and Derivata di Siria) reared by low-input traditional farming system in marginal areas of the Basilicata region.

2. Materials and Methods

2.1. Animal Management and Diet

The trial was carried out during March–May 2017 on a total of 36 unrelated male kids—all born as twins—of the Garganica, Maltese and Derivata di Siria breeds in Muro Lucano (Basilicata region, Southern Italy, latitude: 40°45′13″64 N, longitude: 15°29′17.1″ E, 650 m above sea level). Kids were reared according to the traditional farming system: they were milk-fed, suckling from their dams until they were about 21 days old. Afterwards, three groups of 12 kids per each genotype—the progeny of six dams for each breed—were made, homogeneous for age (21 ± 2 d). The kids were housed in individual pens (1 m^2/head) in an open-sided barn that complies with welfare standards. Each kid had free access to water and received a pelleted feed ad libitum (Table 1) that was formulated in order to meet nutritional requirements [19]. Feed was offered daily at 08:00 a.m. at a rate of 110% of ad

libitum intake, calculated by weighing-back refusals once per week. Feed samples were taken weekly and stored at −20 °C until analyses were performed. In addition to pelleted feed, kids had access to maternal milk throughout the trial period. Suckling occurred twice daily, in the morning at about 07:00 a.m., before the dams were led to pasture and in the evening at 07:00 p.m., when the dams came back from grazing. During suckling time, twin kids were put in the same pen together with their dam. Feed refusals were recorded weekly for each kid in order to calculate the average daily gain (ADG), the average daily feed intake (ADFI) and the feed-conversion ratio (FCR).

Table 1. Feed ingredients (% as fed), chemical (% dry matter basis) and fatty acid composition (% of total fatty acid methyl esters) of the pelleted feed administered to kids.

Ingredient Composition (g/kg as Fed Basis)	
Dehulled soybeans (37% crude protein)	6.00
Corn	31.00
Barley	9.00
Wheat flour middlings	9.00
Faba bean	10.00
Bran	10.00
Dehydrated beet pulp	6.00
Soybean oil	1.00
Sunflower meal	8.00
Molasses	3.00
Soybean hulls (12% crude protein)	4.00
Vitamin mineral premix	3.00
Total	100
Chemical composition (% dry matter)	
Moisture (% as fed)	12.00
Crude protein	16.80
Ether extract	4.60
Ash	9.10
Crude fiber	15.18
NDF (neutral detergent fiber)	33.85
ADF (acid detergent fiber)	10.94
ADL (acid detergent lignin)	2.64
Meat forage units (n/kg dry matter)	1.03
Fatty acid composition (% of total fatty acids methyl esters)	
$C_{12:0}$ (lauric)	0.95
$C_{14:0}$ (myristic)	0.95
$C_{16:0}$ (palmitic)	9.17
$C_{18:0}$ (stearic)	1.15
$C_{20:0}$	0.73
$C_{18:1\ n9\ c9}$ (oleic)	17.91
$C_{18:2\ n6}$ (linoleic)	39.17
$C_{18:3\ n3}$ (α-linolenic)	4.55
$C_{18:3\ n6}$	0.36
$C_{20:3\ n3}$	0.65
$C_{20:4\ n6}$ (arachidonic)	0.21
$C_{22:2\ n6}$	1.17
$C_{22:5\ n3}$ (DPA)	0.54
$C_{22:6\ n3}$ (DHA)	0.30

The dams grazed during the day on a spontaneous vegetation characterized by several shrubs and grass species such as *Spartium* sp., *Rosa canina*, *Prunum spinosa*, *Quercus pubescens*, *Lolium perenne*, *Festuca* sp., *Trifolium pratense*, *Cichorium sativus*, *Avena fatua*, *Avena sterilis*, *Feniculurn* sp., *Vicia sativa*, *Onobrychis viciifolia*, *Lotus corniculatus* and *Thymus serpyllum*. At housing, in the evening, the dams received hay ad libitum and a commercial feed (500 g/head/day).

2.2. Feed Chemical Composition

Samples of the pelleted feed were ground in a hammer mill with a 1 mm screen and analyzed using the following procedures [20]: dry matter (DM; Method 934.01), ether extract (EE; Method 920.39), ash (Method 942.05), crude protein (CP; Method 954.01), crude fiber (CF; Method 945.18), acid detergent fiber (ADF), acid detergent lignin (ADL) (Method 973.18) and amylase-treated NDF (Method 2002.04).

2.3. Slaughtering and Carcass Traits

Kids were slaughtered at 60 days of age by exsanguination, according to the veterinary police rules. The animals were deprived of feed 12 h before slaughter, with free access to water. Kids were weighed immediately prior to slaughter (live weight at slaughter, LWS). The hot carcass, skin and fleece, pluck, full and empty gastrointestinal tract (GIT) were weighed according to the Italian ASPA procedures [21]. Empty body weight (EBW) was calculated by deducting the weight of the full GIT from the LWS. Net hot-dressing percentage was calculated as hot carcass weight/EBW * 100. The carcasses were hung by the Achilles tendon, chilled at 4 °C (80–82% relative humidity) for 24 h and then weighed again. The net cold-dressing percentage was calculated as cold-carcass weight/EBW * 100. The refrigerated carcasses were split into two halves by the midline; the right side was divided into cuts (neck, steaks, brisket, shoulder, abdominal region, loin, leg) according to ASPA methods [21]. The leg and loin were transported from the slaughterhouse to the laboratory using a portable refrigerated box. The two meat cuts were stored at 4 °C for further 24 h and then dissected into tissue components (lean, separable fat and bone) [15].

2.4. Physical Analysis

The pH value was measured on the *longissimus lumborum* muscle of the right half carcass at the time of slaughter (pH 0) and after 24 h of refrigeration at 4 °C (pH 24), using a portable instrument (Hanna Instruments HI 9025, Woonsocket, RI) equipped with a penetrating electrode (FC 23 °C; Hanna Instruments) calibrated at two pH standards points (7.01 and 4.01).

Samples of the *longissimus lumborum* muscle were taken in order to evaluate meat quality characteristics. Meat color (L* = lightness; a* = redness; b* = yellowness) was assessed using a HunterLab MiniScanTM XE Spectrophotometer (4500/L, 45/0 LAV, 3.20-cm-diameter aperture, 10° standard observer, focusing at 25 mm, illuminant D65/10; Hunter Associates Laboratory, Inc.; Reston, VA, USA) by taking three readings for each sample. The instrument was normalized to a standard white tile supplied with the instrument before performing analysis (Y = 92.8; x = 0.3162 and y = 0.3322). The reflectance measurements were performed after the sample had oxygenated in air for at least 30 min, in order to allow the measurements to get stable [22].

Meat tenderness was assessed on raw samples of the *longissimus lumborum* muscle by the Warner–Bratzler shear (WBS) force system using an Instron 5544 universal testing machine (Instron Corp., Canton, MA, USA). The meat samples had a cylindrical shape with a 12.5-mm-diameter; they were assessed in triplicate and sheared perpendicularly to the direction of muscle fibers (load cell: 50 kg; shearing speed: 200 mm/min). Peak force was expressed as kg/cm^2.

2.5. Chemical and Fatty Acid Analyses and Lipid Oxidation

Chemical analysis and fatty acid profile were performed on raw meat of the *longissimus lumborum* muscle using samples devoid of external fat, epimysium and parts with visible metmyoglobin.

The AOAC procedures [20] were used to assess moisture, crude fat, protein and ash. Total lipids were extracted from the homogenized *longissimus lumborum* samples (100 g) according to the chloroform/methanol method [23]. Fatty acids (FA) were methylated using BF3-methanol solution (12% *v*/*v*) [24]. The fatty acid profile was assessed using a Chrompack CP 9000 gas chromatograph, with a silicate glass capillary column (70% cyanopropyl polysilphenylene-siloxane BPX 70 of SGE Analytical

Science, length = 50 m, internal diameter = 0.22 mm, film thickness = 0.25 µm). The temperature program was as follows: 135 °C for 7 min followed by increases of 4 °C per minute up to 210 °C.

The Δ9 desaturase and elongase enzymatic activities were mathematically determined [25] as follows:

Δ9 desaturase 16 index = 100 [(C16:1cis9)/(C16:1cis9 + C16:0)];
Δ9 desaturase 18 index = 100 [(C18:1cis9)/(C18:1cis9 + C18:0)];
Elongase index = 100 [(C18:0 + C18:1cis9)/(C16:0 + C16:1cis9 + C18:0 + C18:1cis9)].

The food risk factors of meat were determined by calculating the atherogenic (AI) and thrombogenic (TI) indices [26]:

$AI = [(C12{:}0 + 4 \times C14{:}0 + C16{:}0)] \div [\Sigma MUFA + \Sigma n{-}6 + \Sigma n{-}3]$;
$TI = [(C14{:}0 + C16{:}0 + C18{:}0)] \div [(0.5 \times \Sigma MUFA + 0.5 \times \Sigma n{-}6 + 3 \times \Sigma n{-}3 + \Sigma n{-}3)/\Sigma n{-}6]$;

where MUFA are monounsaturated fatty acids.

Fatty acids were expressed as percentage (*wt/wt*) of total methylated fatty acids.

Lipid oxidation was evaluated in *longissimus lumborum* muscle samples stored at 4 °C for 48 h after slaughtering by measuring the concentration of 2-thiobarbituric acid reactive substances (TBARS) [27] and expressed as mg malondialdehyde (MDA)/kg meat.

2.6. Collagen Analysis

The *longissimus* muscle was excised from the right half-carcass (chilled for 24 h at 4 °C) between the 4th–5th lumbar vertebrae; samples of approximately 100 g of muscle (wet weight) were removed from the cranial end of the muscle and dry-frozen. The total and soluble collagen content were analyzed according to the method based on the spectrophotometric determination of the hydroxyproline content [28]. Assuming that collagen weighed 7.25 times the measured hydroxyproline weight, the amounts of collagen contents were calculated as follows:

Total collagen = hydroxyproline ∗ 7.25/1000/(weight/250)
Soluble collagen = hydroxyproline ∗ 7.25/1000/(weight/400)

The results were expressed as mg/g of frozen dry matter. Insoluble collagen was calculated from total collagen minus soluble collagen and expressed as µg/mg of frozen dry matter.

2.7. Statistical Analysis

Data were analyzed for variance (ANOVA) using the GLM procedure of SAS software [29]. The statistical model included genotype as the main effect and experimental error. When the genotype effect was significant ($p \leq 0.05$), means were compared by the Bonferroni post hoc test. Results are reported as least squares mean and pooled standard error of the mean (SEM). Significance was declared at $p \leq 0.05$.

3. Results and Discussion

3.1. In Vivo Performance and Slaughtering Data

No differences due to genotype were observed for kids' birth weight, growth performance and slaughter weights (Table 2). The birth weight of kids may depend on the conformation and size of the adults which are typical for each genotype [30].

Table 2. In vivo performance and slaughtering data of kids.

	Genotype			SEM [1]	*p*-Value
	Garganica	Maltese	Derivata di Siria		
Initial body weight (kg)	3.16	2.88	3.06	0.350	0.463
Live weight at slaughter (kg)	11.00	12.44	12.18	2.320	0.592
Average daily gain (kg/d)	0.13	0.16	0.15	0.036	0.459
Average daily feed intake (kg)	0.62	0.70	0.64	0.052	0.549
Feed-conversion ratio (kg/kg)	4.77	4.37	4.27	2.309	0.356
Empty body weight (kg)	9.27	10.16	10.06	1.978	0.742
Skin + fleece (%)	10.18 ^{b}	11.18 ^{a}	10.08 ^{b}	0.637	0.033
Omentum (%)	0.52	0.98	1.61	0.691	0.081
Head (%)	5.99	6.06	6.48	0.415	0.175
Pluck (%)	5.90	6.56	5.77	0.788	0.275
Net hot-dressing percentage	67.72 ^{a}	63.48 ^{b}	67.27 ^{a}	2.553	0.042
Net cold-dressing percentage	64.22 ^{Aa}	56.42 ^{Bb}	62.51 ^{ABa}	3.723	0.015

[1] SEM—standard error of the mean; a, b: $p < 0.05$; A, B: $p < 0.01$.

Comparable results in terms of live weights at slaughter have been reported for suckling kids of the Criollo Cordobes and Anglonubian breeds reared in Argentina according to the traditional system and slaughtered at the same age, i.e., 60 days [31]. Kids of the Maltese breed showed a significantly greater incidence of skin and fleece in comparison with both Garganica and Derivata di Siria ($p < 0.05$). Furthermore, the Maltese kids showed a lower net hot-dressing percentage in comparison with the other two breeds ($p < 0.05$). In the present study, the net hot dressing values recorded were higher than those reported in other experiments [5,31,32], but similar to those observed by other authors in Girgentana [6] and Garganica [15] kids slaughtered at the same age. The lowest net cold-dressing percentage was recorded for the Maltese kids, which was significantly lower in comparison with both the Garganica ($p < 0.01$) and Derivata di Siria ($p < 0.05$) breeds. Several studies have reported that genotype, gender and feeding are the major factors able to affect the slaughter yield which is positively correlated to live weight at slaughter [31,33]. As for the effect of genotype, these differences could be attributed to a higher milk production from their mothers along to differences in size and conformation among breeds [31].

Table 3 shows the section data expressed in terms of percentage of the half-carcass weight. The differences between breeds with regards to carcass conformation and to the incidence of the single meat cuts reflects genetic differences in muscle growth: Maltese kids showed a significantly lower percentage of the loin and shoulder in comparison with the other two breeds ($p < 0.05$) and of the leg than Garganica kids ($p < 0.05$).

The Derivata di Siria and Maltese breeds provided a similar percentage of brisket that was greater than that observed for Garganica kids ($p < 0.01$). Ekiz et al. 2010 [34] reported a significant influence of breed or genotype on certain carcass measurements and indices used as indicators of carcass conformation and size which increase proportionally to slaughter weight.

Genotype did not show any influence on the dissection data of the loin and leg (Table 4). In small ruminants, tissue composition of meat cuts is influenced by nutrition, gender, litter size and body weight [3,6,12]. Moreover, fat depots may develop in a different way in relation to the animal genotype and age; goat carcasses have usually more than 60% dissectible lean and about 5–14% fat [3]. Meat breeds are selected due to an efficient utilization of feed for maximum muscle deposition, while local and indigenous breeds have evolved in response to their ability to use fibrous feeds typical of the production systems in marginal areas, besides their disease resistance [10].

Table 3. Section data (% of half-carcass weight) of kids.

	Genotype			SEM [1]	*p*-Value
	Garganica	Maltese	Derivata di Siria		
Half carcass (kg)	4.66	4.80	4.94	1.192	0.937
		Meat cuts (%)			
Neck	8.04	8.30	7.16	1.133	0.286
Steaks	16.01	16.84	16.49	1.541	0.703
Brisket	9.12 ^{B}	10.85 ^{A}	10.89 ^{A}	0.517	0.001
Loin	7.06 ^{a}	5.78 ^{b}	6.86 ^{a}	0.711	0.031
Abdominal region	4.77	5.86	5.39	0.669	0.070
Leg	31.21 ^{Aa}	30.15 ^{ABb}	29.69 ^{B}	0.388	0.001
Shoulder	19.43 ^{a}	17.80 ^{b}	18.61 ^{a}	0.683	0.045
Shins	2.24	2.35	2.45	0.242	0.409
Perirenal fat	1.53	1.36	1.88	0.786	0.574
Kidney	0.59	0.71	0.58	0.129	0.278

[1] SEM—standard error of the mean; a, b: $p < 0.05$; A, B: $p < 0.01$.

Table 4. Dissection data of the loin and leg (% on weight).

	Genotype			SEM [1]	*p*-Value
	Garganica	Maltese	Derivata di Siria		
Loin weight (kg)	0.332	0.280	0.326	0.076	0.510
Lean (%)	49.98	49.92	43.91	4.759	0.109
Fat (%)	7.68	6.41	6.51	1.900	0.521
Bone (%)	42.34	43.67	49.57	4.853	0.080
Leg weight (kg)	1.44	1.58	1.46	0.394	0.840
Lean (%)	66.29	64.57	61.62	4.783	0.330
Fat (%)	3.39	4.66	5.67	1.818	0.180
Bone (%)	30.32	30.77	32.70	4.783	0.712

[1] SEM—standard error of the mean.

3.2. Physical and Chemical Parameters of Meat

The results of the physical and chemical analyses of meat are reported in Table 5. No significant differences were found between the three breeds for the pH values of meat. The final pH values varied from 5.41 to 5.68 that fall within the acceptable pH range [35] and are optimal for high quality goat meat [36,37].

Table 5. Physical and chemical characteristics and lipid oxidation of meat from the *longissimus lumborum* muscle.

	Genotype			SEM [1]	*p*-Value
	Garganica	Maltese	Derivata di Siria		
pH_0	6.69	6.69	6.78	0.186	0.702
pH_{24}	5.45	5.41	5.68	0.173	0.067
L*	47.82	48.36	46.49	3.043	0.618
a*	6.21 ^{Bb}	7.84 ^{A}	7.64 ^{a}	0.781	0.012
b*	12.01	12.91	12.42	0.893	0.312
WBS (kg/cm^2)	5.15 ^{b}	7.95 ^{a}	7.27 ^{a}	1.553	0.036
Moisture	76.63	74.95	73.94	2.246	0.203
Crude protein	19.36	19.62	19.19	0.994	0.794
Ether extract	2.34 ^{b}	2.89 ^{b}	4.55 ^{a}	1.407	0.045
Ash	1.39	1.63	1.44	0.299	0.451
MDA (mg/kg meat)	0.77 ^{A}	0.38 ^{B}	0.28 ^{B}	0.206	0.005

[1] SEM—standard error of the mean; a, b: $p < 0.05$; A, B: $p < 0.01$.

The pH values found in the present study are comparable to those reported in a previous research carried out in Garganica kids [38] as well as in other goat breeds [6], while they were lower than those recorded for the Criollo Cordobes and Anglonubian breeds [31], thus supporting the hypothesis that kids were not subjected to pre-slaughter stress, that is responsible for high pH values which negatively affect meat visual appearance and quality [39].

Meat color features were quite similar among the three genotypes studied, except for the a* index that was significantly lower in Garganica kids in comparison with Derivata di Siria ($p < 0.05$) and Maltese ($p < 0.01$). Meat obtained in the present study may be classified as light and pale red in comparison with the results reported by other authors [31]. Since the kids in this trial did not differ for gender, litter size, slaughter age and muscle type, the only factor which may have affected meat color is genotype [31,40,41]. Whether these differences may be due to dams' individual eating preferences during grazing which have potential effects on milk must be ascertained.

"Capretto" must show a pink color in order to be appreciated by consumers and in the present study the overall colorimetric features may be judged as satisfactory.

The tenderness varied widely among the three genotypes examined: a significantly lower WBS value was recorded for Garganica kids in comparison with Maltese and Derivata di Siria ($p < 0.05$). The WBS values found in the present study ranged from 5.15 to 7.95 kg/cm^2 which are comparable to those reported by several authors for other goat breeds [6,42,43], but higher in comparison to Garganica kids slaughtered at the same age [15] and to Jonica kids slaughtered at 45 days [44]. The study of the factors influencing meat tenderness is particularly relevant for goat meat due to its lower tenderness compared to lamb/mutton and beef [42]. Among these factors, undoubtedly genotype [10,31,45] plays an important role, along with gender, age at slaughter and animal management system [5,30,42,46,47].

In our study, the chemical composition was not affected by genotype except for the intramuscular fat content, in agreement with previous research [31].

Lipid oxidation of meat is one of the major causes of its qualitative degradation during storage due to the formation of aldehydes responsible for the development of rancid off-flavors and meat color darkening [31]. In the present study, the TBARS values (mg of malondialdehyde-MDA/kg meat) recorded were similar for Maltese and Derivata di Siria kids and significantly lower than those found for the Garganica breed ($p < 0.01$). Although there is evidence on the relationship between meat lipid oxidation and its iron and myoglobin content, in this study we found a higher MDA value in the Garganica breed notwithstanding a similar L value than the other two genotypes and a significantly lower a* value of meat.

The TBARS values recorded for the three genotypes, however, are below the concentration of 2 mg MDA/kg meat, which is considered to be the limit above which rancidity could be revealed by consumers [48].

3.3. Collagen Analysis

Table 6 shows the collagen fractions (total, soluble and insoluble) of the *longissimus lumborum* muscle of kids from the three genotypes. The assessment of the total amount and solubility of collagen is considered to be a simple way to evaluate meat eating quality, with regards to tenderness. No significant effect of genotype was found on neither of the collagen fractions, confirming the results reported by other studies [36]. This may be attributable to the fact that in our study kids had the same age at slaughter. In fact, the distribution of collagen fractions seems to vary widely in relation to animal age [3]. Although the three genotypes did not differ significantly for the soluble and insoluble collagen concentrations; it is possible to suppose that the slightly lower total concentration found for the Garganica breed may have determined a lower shear force.

Table 6. Collagen content of the *longissimus lumborum* muscle (μg/mg lyophilized muscle).

	Genotype			SEM [1]	*p*-Value
	Garganica	Maltese	Derivata di Siria		
Total collagen (μg/mg)	44.96	55.96	58.41	11.654	0.177
Soluble collagen (μg/mg) (%)	22.09 49.49	27.66 49.76	28.84 49.38	4.838 12.651	0.090 0.885
Insoluble collagen (μg/mg) (%)	22.87 50.51	28.30 50.23	29.57 50.62	12.163 12.651	0.647 0.885

[1] SEM—standard error of the mean.

3.4. Fatty Acid Profile of Meat

The fatty acid composition of the *longissimus lumborum* intramuscular fat is shown in Table 7. Among the SFAs, the main fatty acids identified were palmitic, stearic and myristic, in agreement with several studies carried out on kid and goat meat [15,31,49,50]. In particular, meat from Garganica kids showed a significantly lower ($p < 0.05$) amount of total SFAs than the Derivata di Siria breed and a lower concentration of several individual fatty acids such as $C_{10:0}$ ($p < 0.05$), $C_{14:0}$ ($p < 0.01$) and $C_{17:0}$ ($p < 0.05$). Meat from Maltese kids had overall intermediate values, in particular as for myristic acid ($C_{14:0}$) that was significantly lower ($p < 0.05$) in comparison with the Derivata di Siria breed while higher ($p < 0.05$) respect to Garganica kids. No effect of genotype was recorded for the oleic acid concentration ($C_{18:1\ n9\ c9}$), which is the most representative fatty acid among MUFAs, in agreement with previous studies [15,31,50], while the trans-oleic fatty acid concentration, i.e., elaidic acid ($C_{18:1n9t9}$), was highest in meat from Garganica kids, in comparison with both Derivata di Siria ($p < 0.05$) and Maltese ($p < 0.01$). The main trans-monoenoic acids in ruminants are elaidic and vaccenic acid. In adult ruminants, these trans-fatty acids are produced by microbial hydrogenation of linoleic acid and linolenic acid in the rumen; as a consequence, a variety of positional and stereoisomers of both cis and trans-fatty acids may appear in both meat and milk [51]. This finding in Garganica kid meat may by hypothesized as a combination of factors that depend on the fatty acid profile of dam's milk and on a different maturity of the kid's gut at this age.

Meat from Garganica kids showed a higher concentration of both isomers of conjugated linoleic acid (CLA) than the other two breeds ($p < 0.01$). The CLA content in ruminant milk and meat depends on many factors, such as genotype, age and diet [52]. Although CLA accounts for a relatively small amount of the total fatty acid composition of foods, it is very important for human health since it shows positive effects with regard to cancer, atherosclerosis, growth, obesity, osteoporosis and immune responses [53,54].

Garganica meat showed the lowest concentration of α-linolenic acid, with a significant difference than Maltese ($p < 0.05$) and Derivata di Siria ($p < 0.01$) breeds. In the present study, the average $C_{18:3}$ n3 (α-linolenic) concentration was similar [15,49], lower [31] or greater [50] compared to the findings reported by other authors, thus confirming the wide variability of the fatty acid profile of meat due to animal genotype and slaughter age [55]. α-linolenic acid is converted into its longer chain homologs of which the most important for their nutritional interest are $C_{20:5}$ n3 (eicosapentaenoic acid, EPA) and $C_{22:6}$ n3 (docosahexaenoic acid, DHA) since they are important components of animal cell membranes [56]. In turn of a lower concentration of α-linolenic in Garganica meat, we found a significantly higher concentration of EPA ($p < 0.01$) in comparison with the other two breeds. Adversely, Garganica kid meat showed a significantly lower ($p < 0.05$) content of total fatty acids of the n-3 series in comparison with the Derivata di Siria breed.

The n-6/n-3 ratio ranged from a minimum of 5.26 in Derivata di Siria kid meat to 9.22–10.73, respectively for the Maltese and Garganica breeds ($p < 0.01$). A ratio close to one is considered ideal for human health while values less than five are acceptable [56–58]. The n-6/n-3 ratios found in our

study were higher than those found by several authors [47,59,60], but comparable to those reported by Todaro et al. 2000 [61]. The controversial findings indicate that in the pre-ruminant stage this ratio is more influenced by the composition of mother's milk rather than by genotype [62,63].

Table 7. Mean (± SE) fatty acid composition (% of total fatty acid methyl esters) of meat from the *longissimus lumborum* muscle.

	Genotype			SEM [1]	*p*-Value
	Garganica	Maltese	Derivata di Siria		
Total Fatty acids (g/100 g muscle)	2.07	2.31	3.64	0.650	0.802
$C_{10:0\ (capric)}$	0.29 ^{b}	0.26 ^{b}	0.59 ^{a}	0.196	0.042
$C_{12:0\ (lauric)}$	0.97	0.73	1.03	0.364	0.413
$C_{14:0\ (myristic)}$	2.65 ^{Bc}	5.37 ^{b}	7.38 ^{Aa}	1.636	0.002
$C_{16:0\ (palmitic)}$	24.72	21.98	24.79	2.580	0.187
$C_{17:0}$	0.72 ^{b}	1.10 ^{a}	1.04 ^{a}	0.199	0.021
$C_{18:0\ (stearic)}$	14.86	14.09	11.86	2.565	0.199
Total SFA [2]	44.92 ^{b}	46.24 ^{ab}	48.97 ^{a}	2.204	0.037
$C_{16:1\ n7\ (palmitoleic)}$	1.22	1.74	1.99	0.780	0.317
$C_{18:1\ n9\ t9\ (elaidic)}$	2.99 ^{Aa}	0.47 ^{B}	1.23 ^{b}	1.288	0.026
$C_{18:1\ n9\ c9\ (oleic)}$	31.84	34.83	31.06	3.633	0.261
Total MUFA [3]	40.28	40.61	39.10	3.804	0.628
$C_{18:2\ n6\ c9\ c12\ (linoleic)}$	5.18	6.23	5.09	1.782	0.548
$CLA_{\ c9,\ t11}$	0.09 ^{B}	0.01 ^{A}	0.02 ^{A}	0.032	0.003
$CLA_{\ t10,\ c12}$	0.13 ^{A}	0.01 ^{B}	0.02 ^{B}	0.023	0.001
$C_{18:3\ n3\ (\alpha\text{-linolenic})}$	0.21 ^{Bb}	0.59 ^{a}	0.81 ^{A}	0.202	0.002
$C_{20:5\ n3\ (EPA)}$	0.13 ^{A}	0.01 ^{B}	0.01 ^{B}	0.027	0.001
$C_{22:6\ n3\ (DHA)}$	0.14	0.21	0.33	0.260	0.507
Total n-6 [4]	6.71	7.28	6.10	2.066	0.676
Total n-3 [5]	0.66 ^{b}	0.80 ^{ab}	1.15 ^{a}	0.258	0.030
Total PUFA [6]	7.96	8.08	7.25	2.260	0.824
Unidentified fatty acids	6.84	5.07	4.68	1.832	0.579
n-6/n-3	10.73 ^{A}	9.22 ^{A}	5.26 ^{B}	1.925	0.002
PUFA/SFA	0.16	0.18	0.15	0.060	0.785
Δ^{9} desaturase 16 index	4.76	7.08	7.12	2.268	0.210
Δ^{9} desaturase 18 index	68.12	71.21	72.40	5.172	0.428
Elongase index	64.10	67.45	61.69	3.799	0.094
Atherogenic index	1.11 ^{b}	1.18 ^{b}	1.43 ^{a}	0.171	0.032
Thrombogenic index	1.74	1.57	1.68	0.195	0.377

[1] SEM: standard error of the mean; [2] SFA—saturated fatty acids (sum of $C_{10:0}$ + $C_{12:0}$ + $C_{14:0}$ + $C_{15:0}$ + $C_{16:0}$ + $C_{17:0}$ + $C_{18:0}$ + $C_{21:0}$ + $C_{22:0}$ + $C_{24:0}$); [3] MUFA—monounsaturated fatty acids (sum of $C_{14:1}$ + $C_{15:1}$ + $C_{16:1\ c9}$ + $C_{17:1\ c10}$ + $C_{18:1\ t11}$ + $C_{18:1\ t9}$ + $C_{18:1\ t10}$ + $C_{18:1\ c9}$ + $C_{20:1}$ + $C_{24:1}$); [4] Total n-6 (sum of $C_{18:2\ c9;c12}$ + $C_{18:2\ c9;t11}$ + $C_{18:3}$ + $C_{20:3}$ + $C_{20:4}$); [5] Total n-3 (sum of $C_{18:3}$ + $C_{20:3}$ + $C_{20:4}$ + $C_{20:5}$ + $C_{22:6}$); [6] PUFA—polyunsaturated fatty acids (sum of n-6 + n-3); a, b, c: $p < 0.05$; A, B: $p < 0.01$.

No influence of breed was found on the PUFA/SFA ratio that ranged from 0.15 to 0.18. These values are far below the limit of 0.45 recommended for human health [15]. Similarly, no effect of genotype was observed for the indices of Δ9-desaturase, neither 16 nor 18 and elongase enzyme activities.

In this study, the meat from Derivata di Siria kids showed a markedly greater atherogenic index in comparison with the other two goat breeds ($p < 0.05$). The indices of atherogenicity and of thrombogenicity are indicators assessing the level and the interrelation of some fatty acids that have effects on occurrence of coronary heart diseases [26].

4. Conclusions

This comparative study of growth performances, carcass and meat quality traits in Garganica, Maltese and Derivata di Siria kids reared by low-input farming systems and slaughtered at 60 days of age showed that the Maltese breed provided a better meat yield, whereas meat from the Garganica kids was light-rose and more tender. In terms of the nutritional value of meat with regards to the fatty acid composition of intramuscular fat, genotype had no effect on the PUFA/SFA ratio, although Garganica kid meat had a lower content of SFA and atherogenic index. These positive results in terms of potential

benefits for human health may represent an opportunity of valorization and promotion of this breed in order to improve the profitability of low environmental impact rearing systems in marginal areas.

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