Original Article

Effect of pea (*Pisum sativum L.*) as alternative to soybean meal on the productive performances and meat quality traits of Merino crossbred lamb types

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Summary. The increasing use of genetically modified (GM) feeds has aroused many concerns in Europe. The possibility to replace soybean in livestock feedstuffs has led to revalue the use of legume grains such as pea (*Pisum sativum*), lupin (*Lupinus albus*) and field bean (*Vicia faba* var. *minor*). The use of the these legume grains may lower the European dependence of protein rich feeds. The cultivation of legume grains is economically feasible and is widely practiced in South Italy due to the favorable land and climatic conditions and accordingly to the EU provisions on crop rotation. This study was planned in order to evaluate the influence of a diet containing a variety of pea (*Pisum sativum* L., var. *Corallo*) commonly cultivated in South Italy as alternative to a traditional soybean meal based feed on the productive performances and meat quality traits in heavy lambs of two local Merino crossbreeds. The experiment was conducted using two different Merino ethnic groups of 20 male lambs each: "Merinizzata Cavone" (MC) and "Merinizzata Leccese" (ML). All the lambs were raised traditionally with their dams suckling milk until the age of 50 days and then they were weaned using a commercial weaning feed for a week. The lambs of each genetic pool were divided into two homogeneous groups (No. = 10) and fed with one of the two pelletted rations containing: a) soybean meal (SBM) or b) pea feed (PF). Lambs were slaughtered altogether at the age of 100 days. The results show that pea may be successfully used in lamb diets providing satisfactory results in terms of growth performance and meat quality. The MC group has shown good results in terms of lamb growth along with meat yield and quality. This genotype deserves additional investigation in order to get further insight on the response of animals to dietary treatments, that is extremely variable in lamb breeds commonly used for meat production in South Italy.

Keywords: Pea, soybean, Merino lamb, feeding, meat quality

«Impiego del pisello (*Pisum sativum L.*) in sostituzione della farina di estrazione di soia sulle performance produttive e sulle caratteristiche qualitative delle carni in agnelli merinizzati»

Riassunto. L'utilizzo crescente di organismi geneticamente modificati (OGM) nell'alimentazione delle specie di interesse zootecnico suscita molte perplessità in Europa in tema di sicurezza alimentare. La necessità di sostituire una fonte proteica importante come la soia transgenica nei mangimi zootecnici ha indotto a rivalutare l'uso di leguminose da granella potenzialmente alternative alla soia quale il pisello proteico (*Pisum sativum*), il lupino (*Lupinus albus*) ed il favino (*Vicia faba* var. *Minor*). La coltivazione di dette leguminose è sostenibile sia in termini economici, sia a livello ambientale ed è largamente praticata in Italia Meridionale

grazie alle condizioni pedo-climatiche favorevoli ed in attuazione delle disposizioni comunitarie in materia di rotazione delle colture. La presente ricerca ha inteso valutare l'influenza dell'impiego di una varietà di pisello proteico (*Corallo*), comunemente coltivata nelle regioni meridionali, in sostituzione totale della farina di estrazione di soia sulle prestazioni produttive e sulle qualità delle carni in agnelli pesanti di due genotipi Merinizzati. La prova è stata condotta su due gruppi etnici merinizzati, ciascuno di 20 agnelli maschi, denominati rispettivamente "Merinizzata Cavone" (MC) e "Merinizzata Leccese" (ML). Gli agnelli sono stati allevati secondo tecnica tradizionale con le madri fino all'età di 50 giorni e successivamente svezzati con un mangime commerciale di svezzamento per una settimana. Gli agnelli di entrambi i pool genetici sono stati suddivisi in due sottogruppi omogenei (n. = 10) e alimentati con una razione pellettata contenente: a) farina di estrazione di soia (SBM) o b) pisello (PF). I risultati mostrano che il pisello proteico può essere efficacemente utilizzato nelle diete di agnelli in accrescimento in quanto ha fornito risultati soddisfacenti in termini di *performance* produttive e di qualità della carne. In particolare, il gruppo genetico MC ha fatto registrare buoni risultati in termini di accrescimento, rese alla macellazione e caratteristiche qualitative delle carni.

Parole chiave: Pisello, soia, agnelli merinizzati, alimentazione, qualità della carne.

Introduction

The intensification of animal husbandry has led to an increasing use of feedstuffs rich in protein and energy, in order to increase meat yield by reducing the time of fattening and, therefore, the costs of animal management. Soybean has excellent nutritional characteristics so to be considered a necessary ingredient in feedstuffs for different livestock species. Generally used as soybean meal, there has been a great increase of soybean cultivation especially in North and South American countries and more recently the price of soybean has markedly increased, thus raising the costs of animal feeding. Nowadays it has been estimated that more than 70% of the soybean present in the global food system is genetically modified (GM).

The increasing use of GM soybean has aroused many concerns in Europe. There are economic and social worries due to the European dependence on multinational corporations that hold the cultivation know-how and prevent farmers to reproduce GM soybean seeds. As for the effects on environment and on health, that have not been completely dissolved, there seems to be concern for the consequences, especially in the long run, of the dissemination of transgenic crops on the environment as well as on the consumption of GM foods.

The possibility to replace soybean in livestock feedstuffs has led to revalue the use of legume grains such as pea (*Pisum sativum*), lupin (*Lupinus albus*) and field bean (*Vicia faba var. minor*), that have been thoroughly studied for their nutritive value (1, 2). In the last decade many researchers have focused on the use of these legume grains on meat production and quality in farm animals reared in Central and South Italy (3-6).

The European dependence of protein rich feeds would be lowered by the use of these legume grains. More recently, legume grains have been widely cultivated in South Italy due to the favorable land and climatic conditions, in compliance with the recent EU provisions on crop rotation (European Community Regulation no. 73/2009, Art. 68). In the Mediterranean area pea crops may be successfully rotated with wheat crops being more economically feasible than other legume grains. Moreover, their use in feeding autochthonous livestock breeds represents a further potential to exploit the territory and to achieve eco-sustainable animal husbandry.

With regard to its use in animal feeding, pea has a high content of crude protein, a good amino acid profile characterized by a high content of lysine although the content of sulfur amino acids and tryptophan is lower in comparison with soybean (7). Despite its high solubility and protein degradability (8) which makes it a suitable ingredient in feedstuffs for monogastric animals, pea has been used also in ruminant diets, by replacing partially or totally soybean without any significant effects on animal growth and meat quality, as found by researches carried out on Aragonese (9, 10) and Barbaresca breed lambs (4).

The aim of the present study was to evaluate the influence of a diet containing a variety of pea (*Pisum sativum* L., var. Corallo) commonly cultivated in South Italy as alternative to a traditional soybean meal feed on the productive performances and meat quality traits in heavy lambs of two local Merino crossbred types.

Materials and methods

Animals and management

The study was carried out during April-May 2012 at the experimental farm "Cavone", located in the rural area of Spinazzola (South Italy, Apulia: Latitude 40°58'0"N, Longitude 16°5'0"E and 435 m above the sea level), managed in collaboration with the Department of Animal Production, Faculty of Agriculture of the University of Bari.

For several years the Department of Animal Production has carried out a selection programme in order to obtain an ethnic group, named "Merinizzata Cavone", by crossing Ile de France, Gentile di Puglia and early Merino genotypes.

The experiment was conducted using two different merino ethnic groups: the above described Merinizzata Cavone (MC group, No. = 20 male lambs) and a genetic pool obtained by crossbreeding Merino lambs with the Leccese breed ("Merinizzata Leccese", ML group, No. = 20 male lambs).

All the lambs were raised according to the traditional breeding system. Lambs were reared on their mother's milk until weaning at 50 days of age. From the second week of age lambs were given a starter commercial concentrate together with grass hay until they were adapted for a week to the experimental feeds before the beginning of the trial. The lambs of each genetic pool were divided into two homogeneous groups (No. = 10) and fed with one of the two pelletted rations containing: a) soybean meal (SBM) or b) pea (PF).

The chemical composition and the nutritive value of the feedstuffs was assessed (11) and the results are shown in Table 1. The four groups of lambs, separated for each genetic type and treatment, were penned into separate collective boxes where they were kept for the duration of the trial.

The lambs were fed ad libitum for 6 weeks and had free access to oat and vetch hay and water during the experiment, which was conducted in accordance with the Italian regulation that acknowledges the European Community regulation No. 86/609 regarding the protection of animals for experimental and other scientific purposes, in full respect of their welfare.

Fresh feed was given once daily and feed refusals were collected in order to evaluate the voluntary feed intake. The lambs were individually weighed once weekly before feed supply in order to calculate the average feed conversion index (FCI).

Slaughter procedure and carcass measurements

Lambs were slaughtered altogether at the age of 100 days, after 12 hours of restriction from feed but not from water. They were weighed immediately before

Table 1. Chemical composition and nutritive value of the pelletted feeds (%)

	Soybean meal feed (SBM)	Pea feed (PF)
Alfalfa meal dehydrated (17%)	30	22
Corn	22	12
Barley	20	13
Dried sugar beet pulp	3	2
Wheat middling	3	5.5
Flaked soybean	1.5	0
Soybean meal (44%)	15	0
Peas	0	40
Brewer's yeast	2	2
Vitamin-mineral premix	0.05	0.05
Calcium carbonate	0.8	0.8
Dicalcium phosphate	0.85	0.85
Sodium bicarbonate	0.6	0.6
Sodium chloride	0.6	0.6
Magnesium oxide	0.6	0.6
Dry matter (%)	88.5	89.2
Crude protein (% DM)	15.9	15.6
Ether extract (% DM)	2.2	2.2
Crude fiber (% DM)	9.3	9.2
Ash (% DM)	9.3	8.5
N-free extracts (% DM)	51.8	53.7
Neutral detergent fiber (NDF) (% DM)	35.9	34.1
Acid detergent fiber (ADF) (% DM)	15.1	13.4
Acid detergent lignin (ADL) (% DM)	3.8	3.0
Acid insoluble ash (AIA) (% DM)	1.2	1.1
Metabolizable energy (MJ/kg)	10.06	9.58
FU* (n/kg DM)	0.84	0.81

**FU = Fodder units for meat production (INRA, 1978).*

being fasted (final live weight) and when they reached the slaughterhouse (pre-slaughter weight), taking care to cause them minimal stress.

Lambs were slaughtered after electrical stunning, bled by the jugular vein, skinned and eviscerated. Hot carcass weight of each lamb was recorded after removing non-carcass components (head, feet, pluck, gastrointestinal tract), in accordance with the Italian ASPA methods (12).

The esophagus, stomach (rumen, reticulum, omasum and abomasum) and intestines (duodenum, small intestine and large intestine) were accurately weighed before and after emptying in order to calculate the net live body weight. Within 1 hour after slaughter the pH value (pH_1) was measured on the *Longissimus lumborum* (Ll) and *Semimembranosus* (Sm) muscles using a penetrating glass electrode attached to a portable pH-meter (Orion). After 24 hours of refrigeration at 0-4°C the carcasses were weighed again to calculate the cold yield and submitted to further pH measurements (pH_2) on the Ll and Sm muscles. The carcasses were divided into two halves by the midline and the right side was dissected into the following cuts: neck, steaks, brisket, shoulder, loin, abdominal region, shin, leg, testis, kidney and perirenal fat.

The leg and the loin were separated and dissected into their tissue components (lean, separable fat and bone).

Meat instrumental quality and laboratory analysis

Meat colour indexes (L* = Lightness, a* = redness, b* = yellowness) were measured on the Ll and Sm muscles using a spectrophotometer (HunterLab, Miniscan XE™, illuminant D65/10°). Meat samples were placed on a polystyrene tray, over wrapped with an oxygen permeable PVC and stored at 4°C in the dark. Colour was assessed after 2 hours of blooming on the cut surface of meat samples approximately 2 cm thick and devoid of fat (13) by taking 3 readings on each sample.

Both the muscles were split into two subsamples out of which one was used to perform all the analyses on raw meat while the other was cooked in a ventilated oven at 180°C until an internal endpoint temperature of 75°C was reached in the centre of the meat cut, as recorded by a thermocouple (Hanna Instruments, model HI 935005, Sarmeola di Rubano, PD, Italy) inserted into a meat sample placed on the wire rack in the centre of the oven (14). Cooking losses were calculated by weighing the meat samples before and after cooking. Raw and cooked meat samples taken from both the muscles were examined for tenderness using a Warner Bratzler Shear (WBS) testing machine (Instron, model No. 5544, Canton, MA, USA). On raw meat, three cylindrical cores of 1.25 cm diameter were excised from each muscle, while cooked meat was cut in order to obtain three 1 cm^2 section parallelepipeds. All the meat cores (raw and cooked) were sheared perpendicularly to their long axis. Peak force was expressed as kg/cm^2.

Raw and cooked meat samples obtained from the Ll and Sm muscles were homogenised in a grinder with a double rotating blade in order to perform chemical analysis (14) and lipid extraction (15).

Fatty acids were methylated using a BF_3-methanol solution (12% v/v) (16). The fatty acid profile was assessed as previously described by Vicenti et al. (6). Fatty acids were quantified as fatty acids methyl esters. The atherogenic (AI) and thrombogenic (TI) indexes were also calculated (17).

Statistical analyses

Data were analysed for variance (ANOVA) using the GLM procedure of SAS (18). The data on growth performances and carcass measurements were analysed using a model in which the fixed effects were genotype (G; two levels) and diet (D; two levels) and their interaction (GxD). Meat quality parameters assessed on raw and cooked meat were analysed taking into consideration genotype (G), diet (D) and meat status (C; two levels) as fixed effects along with their interactions. Data are reported as least square means and pooled SED values. Means were compared by the Student's *t* test.

Results and discussion

Productive performances in vivo and at slaughter

Table 2 presents the results referring to lamb feed consumption and growth. Regardless the diet admin-

istered, the two groups Merinizzata Cavone groups showed a good carcass conformation of this genotype achieved through a careful selection of the gene pool. Heterosis performed by systematic crossbreeding with the aim to increase the utilization of general and specific combining ability and breed substitution are genetic strategies able to improve the productivity of small ruminant local breeds.

The Merinizzata Cavone lambs fed with SBM showed a markedly higher (P<0.05) average daily gain compared to the PF group. Altogether the Merinizzata Cavone lambs showed a greater voluntary feed intake in comparison with the Merinizzata Leccese genetic pool. Within each genetic group no differences were found between the two dietary treatments as for the consumption of feed.

As a matter of fact the two Merinizzata Cavone groups reached a significantly greater final live weight (P<0.05), regardless of the diet administered.

The feed conversion indexes obtained in this trial ranged between 5.1 and 8.1, being higher than those reported by Lanza et al (19) for lambs slaughtered at the same age, probably due to the different genotype. The best feed conversion ratio was found for the Merinizzata Cavone lambs fed the soybean meal diet, that was lower compared to the other dietary treatment within the same genotype as well as in comparison with the other genotype fed the same diet.

The influence of breed on lamb growth performances and meat quality traits has been thoroughly investigated by several Authors (20-24). In the past sheep genetics focused on the selection of lambs showing better growth performances in turn of moderate feed intake in order to obtain satisfactory meat yields, with significant economic benefits for the farmer. Currently the interest of selection has shifted towards the improvement of meat quality traits, with particular regard to those related to health concerns, thus promoting the selection of leaner animals having a better quality of intramuscular fat, namely more polyunsaturated fatty acids (PUFA) and less saturated fatty acids (SFA) (20, 22, 25).

Table 3 reports the results on slaughtering yields, carcass traits and muscle pH measurements. The Merinizzata Cavone breed lambs reached a significantly higher pre-slaughter weight compared to Merinizzata Leccese lambs, regardless of the diet administered. Significant differences between the two genetic types were found only for lambs fed the pea based diet, which provided a greater incidence (P<0.05) of skin + fleece, empty stomach + intestines and omentum in the Merinizzata Cavone lambs.

Carcasses obtained from the Merinizzata Cavone lambs fed the pea diet showed a significantly higher cold carcass weight compared to the other genotype fed the same diet (P<0.05). The highest chilling loss was recorded for the carcasses of the Merinizzata Leccese lambs fed the pea diet, that was markedly higher compared to the other breed (P<0.05).

No differences between groups were found for the pH_1 values of the Ll muscle (Table 3). After 24 hours of refrigeration of the carcasses, the pH_2 value of the Ll muscle of the Merinizzata Leccese lambs fed the pea diet was significantly higher compared to the other dietary treatment (P<0.01) as well as to the other lamb breed fed the same diet (P<0.05). No differences were found neither between genetic types nor between diets for the pH_1 and pH_2 values of the Sm muscle. Devine

Table 2. Lamb growth performances

	Merinizzata Cavone		Merinizzata Leccese		Effect			
	SBM (n=10)	PF (n=10)	SBM (n=10)	PF (n=10)	Root MSE (df=36)	Genotype (G)	Diet (D)	Interaction (GxD)
Initial live weight (kg)	22.1	21.5	19.5	19.5	0.684	ns	ns	ns
Final live weight (kg)	31.1a	29.5a	25.0b	24.9b	0.359	*	ns	ns
Average daily gain (g/d)	200a	178a	122b	120b	0.098	ns	*	ns
Feed consumption (g/d)	1029	1072	995	970	/	/	/	/
Feed conversion ratio	5.1	6.0	8.1	8.1	/	/	/	/

*Significance levels: a, b: P<0,05; ns=not significant; *P<0.05.*

Table 3. Slaughtering data, carcass traits and pH measurements of the Longissimus lumborum (Ll) and Semimembranosus (Sm) muscles

	Merinizzata Cavone		Merinizzata Leccese		Effect			
	SBM	PF	SBM	PF	Root MSE (df=36)	Genotype (G)	Diet (D)	Interaction (GxD)
Pre-slaughter weight (kg)	29.3a	28.0a	23.2b	22.6b	4.171	*	ns	ns
Empty body weight (kg)	27.0	26.2	21.4	19.9	2.896	ns	ns	ns
Full gastro-intestinal tract (kg)	5.6	5.3	4.5	4.5	0.913	ns	ns	ns
Empty gastro-intestinal tract (kg)	3.3	3.5a	2.7	2.8b	0.518	ns	ns	ns
Hot carcass weight (kg)	20.0	20.7a	17.4	15.5b	3.456	*	ns	ns
Hot carcass yield (%)	53.2	55.6	58.0	53.4	4.856	ns	ns	ns
Skin and fleece (kg)	3.3	3.4a	3.0	2.4b	0.660	*	ns	ns
Omentum (kg)	0.2a	0.2a	0.1b	0.1b	0.073	*	ns	ns
Head (kg)	1.2	1.2	1.0	1.0	0.147	*	ns	ns
Pluck (kg)	1.3	1.3	1.2	1.2	0.217	ns	ns	ns
Cold carcass weight (kg)	19.1	19.9a	16.5	14.7b	3.398	*	ns	ns
Cold carcass yield (%)	50.4	54.9	54.5	51.2	4.129	ns	ns	ns
Chilling loss (%)	4.5	3.8b	5.0	5.2a	0.913	*	ns	ns
pH1 Ll	6.62	6.78	6.80	6.95	0.178	ns	ns	ns
pH2 Ll	5.60	5.76b	5.66B	5.97Aa	0.140	*	*	ns
pH1 Sm	6.61	6.70	6.73	6.81	0.180	ns	ns	ns
pH2 Sm	5.68	5.78	5.62	5.85	0.223	ns	ns	ns

*Significance levels: A, B: P<0.01; a, b: P<0.05; ns=not significant; *P<0.05.*

et al. (26) reported that the ultimate pH value of meat should not exceed 5.8 since higher pH values are held responsible for a dark color of meat that is considered as an undesirable feature.

Teixeira et al. (23) found an influence of genotype on the ultimate pH value of meat as well as a correlation between lamb pre-slaughter live weight and ultimate pH value of the refrigerated carcasses: heavy lambs showed markedly higher pH values of meat after 24 h of refrigeration. It may be hypothesized that in heavy carcasses muscle glycogenolysis occurs slowly thus leading to a poorer acidification of meat that determines greater ultimate pH values.

Results of the anatomical jointing of the right half carcass are reported in Table 4. The right half carcass obtained from the Merinizzata Cavone lambs fed the pea diet was markedly (P<0.05) heavier in comparison with the other lamb genotype fed the same diet. Moreover, the MC group fed the pea diet showed significantly higher proportions of the brisket, loin and perirenal fat (P<0.01) followed by the neck and the shoulder (P<0.05). The influence of genotype on the different proportion of the half carcass joints found in this research may be attributable to the anatomical conformation of the Merinizzata Cavone genetic type that shows a greater development of the anterior trunk as compared to the Merinizzata Leccese group.

The tissue proportion obtained by the dissection of the leg and loin is shown in Table 5. There was no significant influence of genotype on the distribution of lean, fat and bone of the leg. Within the Merinizzata Leccese groups, the leg obtained by the lambs fed the SBM diet contained a significantly higher proportion of fat compared to the PF group (P<0.05). With regards to the dissection of the loin, there was a difference between breeds only for lambs fed the pea diet: the loin cuts obtained by the MC group were significantly (P<0.01) heavier in comparison with the Merinizzata Leccese. Moreover, these cuts showed a lower (P<0.05) incidence of the lean fraction and a greater fat content (P<0.01).

Meat colour parameters of the Ll and Sm muscles are shown in Table 6. Overall, the meat colour features found in this research are quite similar to those reported by other Authors (23; 24) and all the data found fall within the normal range for lamb meat visual acceptability.

The only noticeable difference with regard to the colour of the loin was found for the MC lambs fed the pea diet, which showed a significantly higher (P<0.01)

Table 4. Anatomical jointing of the right half carcass (weight and % of joints)

	Merinizzata Cavone		Merinizzata Leccese		Effect			
	SBM	PF	SBM	PF	Root MSE (df=36)	Genotype (G)	Diet (D)	Interaction (GxD)
Right side weight (kg)	6.54	7.12a	5.64	5.24b	1.287	*	ns	ns
Neck (kg)	0.47 (7.1%)	0.46a (7.0%)	0.40 (7.1%)	0.33b (6.7%)	0.097	*	ns	ns
Steaks (kg)	0.85 (12.6%)	1.00 (15.5%)	0.89 (14.3%)	0.67) (14.6%)	0.331	ns	ns	ns
Brisket (kg)	0.75 (11.5%)	0.72A (10.0%)	0.62 (11.0%)	0.46B (9.9%)	0.151	**	ns	ns
Shoulder (kg)	1.23a (18.3%)	1.20a (17.5%)	0.99b (17.5%)	0.90b (18.0%)	0.196	*	ns	ns
Loin (kg)	0.57 (8.6%)	0.67A (9.9%)	0.50 (8.9%)	0.43B (8.1%)	0.143	**	ns	ns
Abdominal region (kg)	0.27 (4.1%)	0.24 (3.6%)	0.25 (4.4%)	0.18) (3.4%)	0.068	ns	ns	ns
Leg (kg)	2.19 (32.9%)	2.20 (31.6%)	2.00 (32.2%)	1.74 (34.5%)	0.364	ns	ns	ns
Perirenal fat (kg)	0.08 (1.2%)	0.10A (1.5%)	0.05 (0.8%)	0.05B (1.0%)	0.029	**	ns	ns
Kidney (kg)	0.05 (0.7%)	0.04 (0.6%)	0.04 (0.8%)	0.04 (0.8%)	0.007	ns	ns	ns
Shins (kg)	0.70 (2.5%)	0.14 (2.0%)	0.15 (2.6%)	0.14 (2.6%)	0.008	ns	ns	ns
Testis (kg)	0.03 (0.5%)	0.06 (0.8%)	0.02 (0.4%)	0.02 (0.4%)	0.006	ns	ns	ns

*Significance levels: A, B: P<0.01; a, b: P<0.05; ns = not significant; *P<0.05; **P<0.01.*

red index in comparison with the control group and with the other lamb breed fed the same diet.

This trend was also found for the colour of the Sm muscle: meat obtained from the MC-PF group showed a greater red index (P<0.01) as compared to the control group of the same genotype as well as to the Merinizzata Leccese group. The Sm samples of the MC-PF group appeared to be darker, having a L* value significantly lower (P<0.01) respect to the ML-PF group.

The results referring to meat cooking loss and shear force for both the muscles studied are shown in Table 7. There was a dietary effect on the cooking loss of Ll meat samples that was significantly greater for the control diet in both the MC (P<0.01) and ML groups (P<0.05); conversely, no dietary nor genetic effect was found for the Sm meat samples.

The cooking loss found in this study for the Ll muscle is quite similar to the results reported by Vicenti et al. (27) who used the same cooking method. Adversely, Ekiz et al. (28) found lower cooking losses for both the Ll and Sm muscles by using a different cooking method.

As for meat tenderness, the Ll samples obtained from the MC-PF group showed a markedly greater shear force in comparison with the ML-PF group (P<0.05). In this study cooking significantly (P<0.01) worsened meat tenderness, regardless of breed or diet. Miller (29) reported that meat tenderness and juiciness are closely related to the cooking loss. Moreover, as the cooking method affects the fat distribution and subsequent tenderness of meat, a different combination between heat treatment and time of cooking may determine a lower fat loss from the muscle (30). Glob-

Table 5. Anatomical dissection of the hind leg and loin (%)

		Merinizzata Cavone		Merinizzata Leccese		Effect			
		SBM	PF	SBM	PF	Root MSE (df=36)	Genotype (G)	Diet (D)	Interaction (GxD)
Leg (kg)		2.19	2.20	2.00	1.74	0.364	ns	ns	ns
Lean	(%)	61.1	62.3	58.2	61.6	0.226	ns	ns	ns
Fat		10.9	13.5	15.4a	10.2b	0.135	ns	*	ns
Bone		28.0	24.2	26.4	28.2	0.084	ns	ns	ns
Loin (kg)		0.57	0.67A	0.50	0.43B	0.143	*	ns	ns
Lean	(%)	53.4	44.8b	55.9	55.9a	0.072	*	*	ns
Fat		18.8B	29.1A	18.6	18.6B	0.231	*	*	ns
Bone		27.8	26.1	25.5	25.5	0.193	ns	ns	ns

*Significance levels: A, B: P<0.01; a, b: P<0.05; ns = not significant; *P<0.05.*

Table 6. Meat colour indexes of *Longissimus lumborum* and *Semimembranosus* muscles

		Merinizzata Cavone		Merinizzata Leccese		Effect			
		SBM	PF	SBM	PF	Root MSE (df=36)	Genotype (G)	Diet (D)	Interaction (GxD)
Ll	L*	44.39	42.81	45.05	44.21	2.368	ns	ns	ns
	a*	9.82B	12.67A	10.04	11.41B	0.864	*	*	*
	b*	11.64	12.67	11.86	12.72	1.289	ns	ns	ns
Sm	L*	46.37	40.76B	42.95	43.99A	3.525	*	ns	ns
	a*	11.36B	12.86A	11.32	11.54B	0.972	*		*
	b*	12.10	11.59	12.25	12.24	0.950	ns	ns	ns

*Significance levels: A, B: P<0.01; a, b: P<0.05; ns = not significant; *P<0.05.*

Table 7. WBS (kg/cm^2) in raw and cooked meat and cooking loss (%) of the *Longissimus lumborum* (Ll) and *Semimembranosus* (Sm) muscles

		Merinizzata Cavone		Merinizzata Leccese		Effect			
		SBM	PF	SBM	PF	Root MSE (df=36)	Genotype (G)	Diet (D)	Interaction (GxD)
WBS Ll	Raw	1.49	2.50a	2.01	2.18b	0.627	*	ns	ns
	Cooked	3.59	4.28	3.49	3.85	0.790	ns	ns	ns
	Cooking loss	32.1A	24.7B	31.1a	27.9b	4.125	**	ns	ns
WBS Sm	Raw	1.55	1.93	1.86	2.36	0.630	ns	ns	ns
	Cooked	4.19	3.59	3.37	4.51	0.898	ns	ns	ns
	Cooking loss	31.6	31.6	31.4	32.7	4.079	ns	ns	ns

*Significance levels: A, B: P<0.01; a, b: P<0.05; ns = not significant; *P<0.05; **P<0.01.*

ally, the WBS values obtained in the current study are quite similar to those reported by Ekiz et al. (24) who carried out a comparative analysis of meat quality traits for 5 different lamb genotypes. In a previous comparative study performed on 22 different lamb genotypes, Sañudo et al. (31) found that optimal WBS values for lamb meat must be less than 5.5 kg/cm^2, so that consumers may positively judge the eating quality of meat.

Chemical and fatty acid composition

Tables 8 and 9 show the chemical composition of raw and cooked meat in the Ll and Sm muscles, respectively. There were no significant differences between groups for the chemical composition of raw Ll meat samples (Table 8). Cooking significantly affected dry matter (P<0.01), crude protein and total fat

(P<0.05) but not the ash content of meat. The cooking process globally induces structural changes of meat, such as a decrease of its water holding capacity. The loss of water is generally also accompanied by a loss of fat (32), since cooking provokes lipid fusion. As a consequence there is an increase of the protein concentration of meat, in accordance with previous reports (27), that in this study was significantly higher in the Merinizzata Leccese group fed the PF diet (P<0.05).

In meat obtained from the Sm muscle (Table 9), there was a significant effect of breed on protein (P<0.05), total fat (P<0.01) and ash (P<0.01) concentration. Raw Sm meat samples from the Merinizzata Cavone lambs fed the PF diet showed a significantly (P<0.01) greater fat and ash content in comparison with the other groups.

Sañudo et al. (33) reported that differences in fatness, within one breed or crossbreed, may be more evident at some stages of growth or that they may depend on the growth rate of lambs. The chemical composition of meat in this study is quite similar to that reported by other Authors for lambs slaughtered at approximately the same age and live weight (4; 34).

The results of the fatty acid composition of raw and cooked meat obtained from the Ll muscle are presented in Table 10. The majority of fatty acids found were in order oleic (C18:1$_{\omega 9\ c}$), palmitic (C16:0) and stearic (C18:0) acids, as also reported by other Authors (35; 36). There were no differences between groups as for the proportion of total saturated (SFA), monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA), thus showing that neither the genotype nor the diet influenced the fatty acid profile of meat obtained from the Ll muscle.

Table 11 shows the fatty acid composition of raw and cooked meat samples of the Sm muscle. As for the main fatty acids, there were no noticeable differences neither among genetic groups nor among dietary treatments.

Differences in the fatty acid content of meat are closely related to many aspects, namely the animal species, breed, sex, weaning age, body weight at slaughter, production system, dietary fat intake, muscle and met-

Table 8. Chemical composition (%) of raw and cooked meat samples of the *Longissimus lumborum* (Ll) muscle

	Merinizzata Cavone				Merinizzata Leccese				Effect				
	SBM		PF		SBM		PF						
	Raw	Cooked	Raw	Cooked	Raw	Cooked	Raw	Cooked	Root MSE (df=149)	G	D	C	Interactions
Moisture	75.1	65.9	76.2	60.7	76.3	65.5	80.0	56.9	7.259	ns	ns	**	DxC=**
Crude protein	20.6	28.9b	18.9	33.5b	19.4	29.5b	16.1	37.1a	3.603	*	ns	*	GxD=*
Total fat	3.1	3.2	3.1	3.3	3.0	3.2	2.8	3.6	2.436	ns	ns	*	DxC=*
Ash	1.2	2.0	1.8	2.5	1.3	1.8	1.1	2.4	2.770	ns	ns	ns	ns

G = genotype; D = diet; C =cooking.
*Significance levels: A, B: P<0.01; a, b: P<0.05; ns = not significant; *P<0.05; **P<0.01.*

Table 9. Chemical composition (%) of raw and cooked meat samples of the *Semimembranosus* (Sm) muscle

	Merinizzata Cavone				Merinizzata Leccese				Effect				
	SBM		PF		SBM		PF						
	Raw	Cooked	Raw	Cooked	Raw	Cooked	Raw	Cooked	Root MSE (df=149)	G	D	C	Interactions
Moisture	75.8	65.9	75.7	61.6	75.8	66.2	79.3	57.1	7.259	ns	ns	**	DxC=**
Crude protein	20.1	27.3	18.5a	31.1	20.6	27.9	17.1b	36.3	3.603	*	ns	*	GxD=*
Total fat	2.7B	3.1	3.1A	4.3	2.3B	2.9	2.4B	3.6	2.436	**	ns	**	DxC=**
Ash	1.4B	3.7	2.7A	3.0	1.3B	3.0	1.2B	3.0	2.770	**	ns	ns	DxC=*

G = genotype; D = diet; C =cooking.
*Significance levels: A, B: P<0.01; a, b: P<0.05; ns = not significant; *P<0.05; **P<0.01.*

Table 10. Fatty acid profile (%) (g/100 g identified fatty acid methyl esters) of raw and cooked meat samples of the *Longissimus lumborum* muscle

	Merinizzata Cavone				Merinizzata Leccese				Effect				
	SBM		PF		SBM		PF						
	Raw	Cooked	Raw	Cooked	Raw	Cooked	Raw	Cooked	Root MSE (df=149)	G	D	C	Interactions
C 14:0	4.78	4.09	4.31	4.48	4.61	4.22	4.00	3.86	0.921	ns	ns	ns	ns
C 14:1	0.13	0.11	0.10	0.08	0.18	0.09	0.11	0.07	0.172	ns	ns	ns	ns
C 15:0	0.51	0.43	0.43	0.49	0.53	0.49	0.46	0.44	0.107	ns	ns	ns	ns
C 15:1	0.18	0.16	0.18	0.16	0.19	0.17	0.15	0.14	0.031	ns	ns	ns	MxC=**
C 16:0	23.59	23.12	24.50	25.04	22.75	23.87	23.31	24.27	1.178	ns	**	**	ns
C 16:1 ω7	1.42	1.40	1.60a	1.64	1.50a	1.52	1.09b	1.47	0.283	*	ns	ns	ns
C 17:0	0.64	0.58	0.55	0.56	0.62	0.57	0.53	0.52	0.954	ns	*	ns	GxD=*
C 17:1	1.18	1.09	1.03	1.08	1.18	1.13	0.91	1.14	0.223	ns	ns	ns	ns
C 18:0	16.34	15.78	14.97b	15.41	16.29	15.26	17.50a	16.31	1.775	*	ns	ns	ns
C 18:1 ω9 t	0.54	0.81Aa	0.48	0.42B	0.63	0.55b	0.46	0.43	0.207	ns	*	ns	DxM=*
C 18:1 ω9 c	35.02	36.36	36.75	34.86	34.34	35.03	33.83	35.18	2.434	**	ns	ns	ns
C 18:1 ω7	0.77	0.86	0.89	0.86	0.82	0.84	0.88	0.96	0.218	ns	ns	ns	ns
C 18:2 ω6 t	0.10	0.12	0.17	0.12	0.11	0.11	0.11	0.14	0.039	ns	**	ns	GxM=*GxC=*
C 18:2 ω6 c	3.99	4.49	3.96b	4.29	4.69	5.04	4.89a	4.53	0.754	**	ns	ns	ns
C 18:3 ω6	0.11	0.10	0.09	0.08	0.10	0.10	0.09	0.09	0.038	ns	ns	ns	ns
C 18:3 ω3	0.66b	0.66	0.58	0.56	0.79Aa	0.73A	0.59B	0.56B	0.084	*	**	ns	DxG=*
C 20:0	1.14	0.98	0.99	1.01	1.22a	1.04	0.99b	0.86	0.176	ns	ns	ns	ns
CLA (9c,11t)	0.09	0.08	0.06	0.10	0.10	0.08	0.09	0.10	0.054	ns	ns	*	ns
CLA (10t,12c)	0.05	0.02	0.04	0.02	0.06C	0.00D	0.01	0.02	0.031	ns	*	ns	ns
C 20:1 ω9	0.01	0.00	0.01	0.02	0.02	0.00	0.00	0.01	0.023	ns	ns	ns	ns
C 20:2 ω6	0.04	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.027	ns	ns	ns	ns
C 20:3 ω6	0.06	0.08a	0.07	0.05b	0.06	0.08	0.07	0.07	0.024	**	*	ns	ns
C 20:3 ω3	0.37	0.73	0.56	0.52	0.47	0.75	0.66	0.66	0.229	**	ns	ns	DxC=*
EPA	0.04	0.09	0.04	0.05	0.06	0.10	0.07	0.08	0.040	**	**	ns	DxM=*
C 22:5 ω6	0.00	0.04	0.02	0.02	0.00b	0.03	0.05a	0.03	0.039	*	ns	ns	DxM=*
C 22:5 ω3	0.16	0.25	0.21	0.17	0.22	0.28	0.26	0.16	0.113	**	*	ns	ns
DHA	0.02	0.08A	0.02	0.00B	0.01	0.06	0.03	0.02	0.040	*	**	ns	GxM=*; DxC=*
SFA	47.03	45.01	45.77	47.01	46.03	45.46	46.81	46.28	1.861	ns	**	ns	ns
MUFA	39.28	40.83	41.06	39.15	38.89	39.37	37.44	39.42	2.323	**	ns	ns	ns
PUFA	5.73	6.85	5.92	6.07	6.77	7.46	7.02	6.57	1.140	**	*	ns	ns
Non identified	7.94	7.29	7.24	7.76	8.29	7.70	8.71	7.71	1.132	*	ns	ns	ns
UFA	45.02	47.69	46.98	45.22	45.66	46.83	44.47	45.99	2.061	ns	**	ns	ns
UFA/SFA	0.96	1.06	1.02	0.96	0.99	1.03	0.95	0.99	0.081	ns	**	ns	GxD=*
MUFA/SFA	0.83	0.90	0.90	0.83	0.84	0.86	0.80	0.85	0.079	**	*	ns	ns
PUFA/SFA	0.12	0.15	0.12	0.12	0.14	0.16	0.15	0.14	0.026	**	**	ns	ns
ω3	1.27	1.83	1.43	1.32	1.56	1.94	1.62	1.51	0.408	**	**	ns	DxC=*
ω6	4.31	4.90	4.38	4.63	5.04	5.42	5.29	4.93	0.803	**	ns	ns	ns
ω6/ ω3	3.59	2.75b	3.16	3.61a	3.24	2.85	3.30	3.29	0.622	ns	**	ns	DxC=*
CLA	0.14	0.11	0.10	0.12	0.16	0.09	0.10	0.12	0.583	ns	*	**	ns
AI	0.59	0.83	0.89	0.95	0.90	0.87	0.88	0.86	0.126	ns	ns	ns	ns
TI	1.73	1.49	1.60	1.72	1.62	1.52	1.69	1.64	0.132	ns	**	ns	DxC=*

G = genotype; D = diet; C =cooking.
*Significance levels: A, B: P<0.01; a, b: P<0.05; ns = not significant; *P<0.05; **P<0.01.*

abolic type of the muscle fibres (21, 24, 25). However, it is well documented that meat from ruminants is only moderately influenced by the diet because of the hydrogenating action of the rumen microorganisms.

Lamb meat production is very variable since each country/region has own traditional production systems, a wide range of genetic breeds usually reared, typical slaughtering weights and carcass evaluation

Table 11. Fatty acid profile (%) (g/100 g identified fatty acid methyl esters) of raw and cooked meat samples of the *Semimembranosus* (Sm) muscle

	Merinizzata Cavone				Merinizzata Leccese				Effect				
	SBM		PF		SBM		PF						
	Raw	Cooked	Raw	Cooked	Raw	Cooked	Raw	Cooked	Root MSE (df=149)	G	D	C	Interactions
C 14:0	4.24	5.07	4.52	5.04	4.30	4.15	4.63	5.15	0.921	ns	ns	ns	ns
C 14:1	0.09	0.12	0.07	0.09B	0.11	0.11	0.14	0.45A	0.172	ns	**	ns	ns
C 15:0	0.42	0.51	0.48	0.50	0.49	0.46	0.54	0.54	0.107	ns	ns	ns	ns
C 15:1	0.14b	0.18a	0.16	0.17	0.17	0.17	0.16	0.18	0.031	ns	ns	ns	MxC=**
C 16:0	23.53	24.28	23.53	24.84	22.49	23.23b	23.89	24.79a	1.178	*	ns	**	ns
C 16:1 ω7	1.72	1.61	1.70	1.69	1.49	1.50	1.49	1.49	0.283	ns	ns	ns	ns
C 17:0	0.51	0.55a	0.57	0.58A	0.55	0.55a	0.44	0.42Bb	0.954	ns	*	ns	GxD=*
C 17:1	0.9B3	1.02	1.04	1.02	1.30A	1.03	1.16	1.06	0.223	ns	ns	ns	ns
C 18:0	14.62	13.99	14.17	14.10	15.03	14.67	15.95	15.21	1.775	*	ns	ns	ns
C 18:1 ω9 t	0.47	0.48	0.41	0.50	0.55	0.51	0.57	0.54	0.207	ns	*	ns	DxM=*
C 18:1 ω9 c	37.58	35.64	36.96a	36.51a	35.41	35.31	33.34b	33.22b	2.434	**	ns	ns	ns
C 18:1 ω7	1.23Ac	0.93d	0.89B	0.87	0.88B	0.92	0.90	0.98	0.218	ns	ns	ns	ns
C 18:2 ω6 t	0.11	0.11	0.13	0.12	0.11	0.11	0.13	0.23	0.039	ns	**	ns	GxM=*; GxC=*
C 18:2 ω6 c	4.57	4.42	4.08	3.89	5.12	4.96	4.89	4.68	0.754	**	ns	ns	ns
C 18:3 ω6	0.08	0.09	0.10	0.09	0.12	0.07	0.11	0.09	0.038	ns	ns	ns	ns
C 18:3 ω3	0.62b	0.68	0.61	0.60	0.74a	0.72	0.61b	0.60b	0.084	*	**	ns	DxG=*
C 20:0	0.98	0.98	1.15	1.09	1.12	1.06	0.99	0.95	0.176	ns	ns	ns	ns
CLA (9c,11t)	0.19A	0.04B	0.09B	0.06	0.08B	0.08a	0.10B	0.01b	0.054	ns	ns	*	ns
CLA (10t,12c)	0.04	0.05	0.02	0.03	0.03	0.05	0.03	0.02	0.031	ns	*	ns	ns
C 20:1 ω9	0.00	0.00	0.01	0.02	0.00	0.02	0.01D	0.05C	0.023	ns	ns	ns	ns
C 20:2 ω6	0.08Aa	0.04b	0.03B	0.03	0.06	0.06	0.05	0.04	0.027	ns	ns	ns	ns
C 20:3 ω6	0.07	0.08	0.05	0.05b	0.09	0.10	0.08a	0.07	0.024	**	*	ns	ns
C 20:3 ω3	0.59	0.77	0.58	0.49	0.97	0.89	0.74	0.72	0.229	**	ns	ns	DxC=*
EPA	0.09b	0.12a	0.05	0.05b	0.15a	0.13	0.10	0.10	0.040	**	**	ns	DxM=*
C 22:5 ω6	0.04	0.04	0.02	0.00b	0.06	0.08	0.05	0.05a	0.039	*	ns	ns	DxM=*
C 22:5 ω3	0.24b	0.22b	0.18	0.15	0.38a	0.36a	0.28	0.22b	0.113	**	*	ns	ns
DHA	0.07A	0.04B	0.02b	0.01	0.09	0.11A	0.06	0.03B	0.040	*	**	ns	GxM=*; DxC=*
SFA	44.31	45.39	44.43	46.17	44.00B	44.14B	46.46A	47.08A	1.861	ns	**	ns	ns
MUFA	42.19	40.01	41.26a	40.90a	39.93	39.61	37.80b	37.99b	2.323	**	ns	ns	ns
PUFA	6.84	6.74	6.01	5.62	8.04	7.77	7.27	6.91	1.140	**	*	ns	ns
Non identified	6.65	7.84	8.28	7.30	8.02	8.46	8.46	8.00	1.132	*	ns	ns	ns
UFA	49.03	46.76	47.27	46.52	47.97a	47.38a	45.07b	44.90b	2.061	ns	**	ns	ns
UFA/SFA	1.10	1.03	1.06	1.01	1.09	1.07	0.97	0.95	0.081	ns	**	ns	GxD=*
MUFA/SFA	0.95	0.88	0.93	0.88	0.91	0.89	0.81	0.80	0.079	**	*	ns	ns
PUFA/SFA	0.15	0.14	0.13	0.12	0.18	0.17	0.15	0.14	0.026	**	**	ns	ns
ω3	1.62B	1.84a	1.46	1.31b	2.34Aa	2.23a	1.80b	1.68b	0.408	**	**	ns	DxC=*
ω6	4.98	4.80	4.42	4.20b	5.58	5.39	5.32	5.19a	0.803	**	ns	ns	ns
ω6/ω3	3.22a	2.63	3.06	3.30	2.39b	2.46b	3.02	3.20a	0.622	ns	**	ns	DxC=*
CLA	0.23A	0.09B	0.12B	0.09	0.11B	0.13	0.13BC	0.03D	0.583	ns	*	**	ns
AI	0.83	0.97	0.88	0.97	0.83	0.84b	0.94	1.01a	0.126	ns	ns	ns	ns
TI	1.47	1.54	1.53	1.64	1.39b	1.42b	1.62a	1.68a	0.132	ns	**	ns	DxC=*

G = genotype; D = diet; C =cooking.
*Significance levels: A, B, C, D: P<0.01; a, b: P<0.05; ns = not significant; *P<0.05; **P<0.01*

criteria depending on the local customs and sensory preferences of people (25, 37).

Therefore, most of the literature focuses on the chemical and fatty acid composition of raw meat in order to achieve comparable results. Limited research has been carried out on cooked meat, although the assessment of cooked meat nutritional properties may provide useful information on meat's effective healthi-

ness since lamb meat is exclusively consumed cooked in our diet. The results referring to the effect of cooking on meat chemical and fatty acid composition are quite discordant, varying among the different animal species and meat cuts and depending on the different cooking processes used affected by time, medium and temperature (32).

Conclusions

This study is part of a wider research project carried out over the last decade by the Department of Animal Production aiming to test legume grains alternative to soybean in feeding for different livestock animals. The results obtained in this study show that pea may be successfully used in lamb diets providing satisfactory results in terms of growth performance and meat quality. The "Merinizzata Cavone" genetic type has shown good results in terms of lamb growth along with meat yield and quality. This genetic type may represent a good potential for lamb meat production in South Italy.

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