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PAPER

Growth performance, carcase characteristics and meat quality of crossbred bulls and heifers from double-muscled Belgian Blue sires and Brown Swiss, Simmental and Rendena dams

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ABSTRACT

Growth, conformation, carcase and meat quality traits of crossbred calves obtained in the Alps from selected Belgian Blue sires (BB) and Brown Swiss (BS), Simmental (Si) and Rendena (Re) dams were studied, emphasising differences on dairy and dual purpose maternal breed. Six pens with five heifers (3 BB × BS, 1 BB × Si, 1 BB × Re) and six pens with four young bulls (2 BB × BS, 1 BB × Si, 1 BB × Re) were used. In total 53 crossbred calves were tested: 30 from BS dams and 23 from dual purpose (12 from Si and 11 from Re dams). Growth performances were measured, carcases were scored for muscle conformation and fatness, the fifth rib was dissected, and the *Longissimus thoracis* (LT) was analysed. The maternal breed had significant effects when the calves from dairy cows (BB × BS) were compared to those of the dual purpose breeds (BB × Si and BB × Re), as at slaughter the former were 1.2% taller, 6.0% less *in vivo* muscle score, 5.0% less *carcase* muscle score, with a 13% greater proportion of bone in the rib, and their LT had 12.5% less drip losses, but 3% greater cooking losses and 25% greater shear force. It was concluded that when using a BB as a sire, the dam breed has influence on the growth performance traits of the derived crossbreds, but the major influence would regard the carcase and meat quality traits. In the Alps, these differences are reflected in different sold prices of the crossbred calves from dairy and dual purpose breeds at local auctions.

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Belgian blue; beef; crossbreeding; dairy breeds; dual purpose breeds

Introduction

The valleys of the Alps gave origin to several cattle breeds, the most widespread of which are the Brown Swiss (BS) and Simmental (Si). The Brown cattle reared in the Alpine regions of Austria, France, Germany, Italy, Slovenia and Switzerland (Herens) are currently mainly derived from US Brown Swiss breed, heavily selected for dairy production. The Simmental, on the contrary, is selected mainly as dual purpose breed in Austria, Germany, Italy, Slovenia and France, is more selected toward milk production in France (Montbeliarde), and is crossbred with Red Holstein in Switzerland. Several other dual purpose Alpine breeds are reared in Austria, France, Germany, Italy and Switzerland. The majority of the breeders associations of these cattle breeds are grouped in the European Federation of the Cattle Breeds of the Alps System (FERBA, http://www.ferba.info).

Respect to Holstein Friesian, Alpine breeds are characterised by lower milk yield but by greater fat and protein content, better milk coagulation and curd firming properties and higher cheese yield and recovery of milk nutrients in curd (Stocco et al. 2017a, 2017b). To compensate for the lower milk production often recorded in the mountain the local farms, especially the traditional ones, practice the summer transhumance to highland pastures (Battaglini et al. 2014; Zendri et al. 2016) and produce high quality milk (Bittante et al. 2015; Mele et al. 2016) and high priced typical PDO cheeses (Bittante et al. 2011a, 2011b; Bergamaschi et al. 2016). An important way to partly compensate the low income from milk of the traditional farms in the mountains is to increase revenues from meat production, both as calves exceeding the need for replacement, and as culled cows. They are characterised by a high proportion of new-born calves

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sold for meat production, because of high fertility and longevity (Toledo-Alvarado et al. 2017) and of low replacement needs, and usually these calves belongs to breeds characterised by higher selling price and weight. Moreover, a high proportion of cows from these herds are mated to beef bulls, like Limousine and Simmental, and more recently especially to double muscled sires like the Belgian Blue (BB), and Piemontese, for the production of high priced crossbred calves (Dal Zotto et al. 2009; Mc Hugh et al. 2010).

Crossbreeding between dairy cows and beef bulls has been previously reviewed (More O'Ferrall 1981), but since then the interest, at least in specialised dairy farms, has diminished due to increased replacement rate and decreased fertility of high yielding dairy cows (Phuong et al. 2015). The interest toward crossbreeding of dairy and dual purpose cows with beef bulls is now increasing, also in the intensive dairy farms of the plains: because of the availability of X-sorted semen that allows to reduce the number of females destined to the production of the replacement heifers; because the spreading of crossbreeding among dairy breeds that increases the fertility of dairy cows; and because of the genetic improvement of beef breeds, and especially of double-muscled ones, that reduces the calving difficulties of offspring and increases their monetary value.

Crossbreeding of dairy cows with beef sires was especially focussed on comparisons among sire breeds. Regarding the breed of the cows, the information available is concentrated especially on Holstein Friesian cows, while it is very scarce or null for the cows belonging to the breeds of Alpine origin. In these last years, the most important dairy (BS) and dual purpose breeds have been heavily selected for milk yield. The effect of double muscled sire on the beef performance, carcase and meat quality, of the offspring claves is notable (Dal Zotto et al. 2009), but less clear is the dam breeds contribution. To this regard, the existence of a maternal effect, at least between specialised dairy and dual purpose maternal breeds, is suggested by different price of crossbred calves (Dal Zotto et al. 2009). Based on different prices at calving auditions of crossbred calves, differences between Simmental (widespread and heavily selected) and Rendena (endangered Alpine breed) dam breeds can also be suggested, although to a lesser extent.

Therefore, the objective of the present study was the characterisation of growth, conformation, carcase and meat quality traits of male and female crossbred calves obtained from recently selected Belgian Blue sires and dairy (BS), and dual purpose [Si, and Rendena (Re)] dams.

Materials and methods

Animals and diets

The present study was part of a wider project aiming at the analysis of the possibility of using low protein diets as a way for the reduction of nitrogen excretion of homozygous or heterozygous double muscled calves (Schiavon et al. 2011, 2012). The project was approved by the 'Ethical Committee for the care and the use of experimental animals' of the University of Padova.

The calves used for this study were obtained in the Italian alpine province of Trento from the artificial insemination of cows of the dairy Brown Swiss (BS), dual purpose Simmental (Si) and local dual purpose Rendena (Re) breeds with the semen of double-muscled Belgian Blue (BB) sires. The Brown Swiss cows were registered in the National Brown Swiss Herd Book (ANARB, Bussolengo, VR, Italy) and they were generated from Brown Swiss bulls selected according a typical progeny testing for milk production and quality, type and fitness traits and with genetics derived mainly from Italian, American, German and Swiss populations (Cecchinato et al. 2015). The Simmental cows were registered in the National Simmental Herd Book (ANAPRI, Udine, Italy) and they were daughters of Simmental bulls selected for dual purpose through a performance testing for beef traits and a progeny testing for dairy and muscle conformation traits, mainly deriving from Italian, German and French (Montbeliarde) populations (Cecchinato et al. 2015). The Rendena cows were registered in the National Rendena Herd Book (ANARE, Trento, Italy) and they were daughters of young Rendena bulls selected on the basis of the performance testing for beef traits and the pedigree information for dairy traits (Mazza et al. 2014).

The double-muscled Belgian Blue young bulls (eight bulls), all registered in the Belgian Herd Book of this breed, were imported into Italy and tested by Alpenseme (Toss di Ton, TN, Italy) on local dairy cows for the production of crossbred calves aimed at optimising calving ease of the dairy cows and the monetary value of the crossbred calves sold locally at auction (Dal Zotto et al. 2009).

The crossbred calves were bought by the Provincial Breeders Federation of Trento between 3 and 4 weeks of age and weaned in a single barn following the same protocol. After weaning the calves were moved to the experimental farm 'Lucio Toniolo' of the University of Padova, where the trial was carried out with the aims of testing the three dam breeds using two diets differing in dietary crude protein (CP) content.

The number of experimental animals was quantified, as described by Lerman (1996), as the minimal number to detect significant differences ($p = .05$; power = 90%) of growth rate among groups of 0.100 kg/day, with an anticipated within-group standard deviation for growth rate of 0.150 kg/day. Thirty-two bull calves [initial body weight (BW) 256.0 ± 30.7 kg] and 30 heifer calves (BW 221.8 ± 26.0 kg) were involved. After arrival, all calves were vaccinated against bovine rhinotracheitis virus, parainfluenza 3 virus and modified live bovine respiratory syncytial virus and injected with 2.5 mg/kg BW of Tulathromycin. The calves were housed in 14 fully slatted floor pens with four bull calves or five heifer calves each. The first and the last pen, with male calves, were retained as 'border' pens and not considered for experimentation. Thus, six pens with five heifers (3 BB × BS, 1 BB × Si, 1 BB × Re) and six pens with four young bulls (2 BB × BS, 1 BB × Si, 1 BB × Re) were used. In total 30 calves from dairy cows (all BB × BS, 3 females or 2 males per pen) and 23 from dual purpose cows (12 BB × Si and 11 BB × Re, one per type per pen) were tested. Four pens (two of males and two of females) were used to test the use of a 'high protein' (HP) conventional diet, four pens to test a 'low protein' (LP) diet and four pens (HP→LP) to test a phase feeding characterised by a HP diet in the first part of experiment (90 days) followed by a LP diet in the second part of fattening (94 days).

After a transition diet for 40 days in which meadow hay was progressively replaced by the experimental conventional diet, the two experimental diets were fed as total mixed rations. The ingredients, chemical composition and nutritional value of the two rations were described in detail in a previous publication on the same project focussed on the effect of low CP feeding (Schiavon et al. 2013). In short, the ingredients were: ground corn grain [360 or 400 g/kg of ration dry matter (DM)], corn silage (250 or 276 g/kg DM), dried sugar beet pulp (102 or 113 g/kg DM), soybean meal (126 or 33 g/kg DM), wheat bran (63 or 70 g/kg DM), wheat straw (60 or 66 g/kg DM) and supplements (39 or 45 g/kg DM). The HP ration was formulated for achieving 139 g/kg DM of CP density, whereas the LP ration (102 g/kg DM) was obtained by reducing only the level of inclusion of soybean meal from 126 to 33 g/kg DM and increasing accordingly all the other ingredients. Metabolisable energy content of the diets was 13.0 MJ/kg DM. The amount of each feed ingredient loaded into the mixer-wagon and the weight of the mix uploaded in the manger of each pen were recorded daily and the orts remained in the mangers were weighed and sampled by pen weekly. As animals in pens were not fed individually, DM intake (DMI) and feed efficiency were computed on pen basis.

Measurements, controls and analysis

An operator, licenced for carcase evaluation according to the SEUROP grading system, evaluated monthly the body condition of each bull. Body condition was expressed in terms of expected carcase conformation and fat covering according to the SEUROP grid (European Community 2006). Thus, conformation was linearly scored from S + (all muscle profiles extremely convex; exceptional muscle development) to P− (all muscle profiles concave to very concave; very poor muscle development) considering the profiles of shoulders, loins, rump, tights and buttocks (Schiavon et al. 2010). Conformation was transformed in numerical terms: S+ = 6.33, S = 6, S− = 5.66, P+ = 1.33, P = 1.00, P− = 0.66. Fat covering was linearly scored, by a combined visual and palpation approach, considering the presence and the thickness of subcutaneous fat depots at specific points of the body, from 1 (very lean: no palpable fat is detectable, the ribs, the bone structure and the head of the tail are very prominent) to 5 (very fat: thick fat depots are present over the shoulders, the ribs and around the head of the tail, bone structure is no longer visible).

Health status was monitored daily by a technician and three times per week by a veterinarian, following the experimental protocol for animal care. After 105 days on trial a heifer from a Rendena dam was removed from the trial because of a compromised health status and its data were not used for statistical analysis. Moreover, during the second part of the trial three bulls (two from Simmental and one from Brown Swiss dams) and one heifer (from Brown Swiss dam) exhibited a mild alteration of locomotion (locomotion score 2) but, according to veterinary advise, they were not separated from the others.

Carcass traits

At the end of the fattening trial, the animals were fasted for 1 day and slaughtered. Slaughtering occurred after 159 d on trials for all heifers and after 204 and 222 days on trial for 16 and 8 young bulls, respectively (the males were randomly divided between the two groups, with the limits that all thesis, maternal breed and pens be represented in each group). Carcasses were individually weighed and scored for muscle conformation and fat covering according to the SEUROP system (European Community 2006). Dressing percentage was computed as the ratio between the carcase weight after 24 h from slaughter and BW.

Twenty-four hours after slaughter the whole cut of the fifth rib was collected. The entire rib was vacuum packed, moved to the laboratory and aged at 4 °C in a chilling room for 10 days. After ageing, drip losses were assessed as the ratio of the difference between the wet and the dried empty bag and the weight of the rib. Muscles pH was measured using a Delta Ohm HI-8314 pH-meter (Delta Ohm, Padova, Italy) 10 days *post-mortem*. Colour parameters were measured, after 1 h of air exposure, on *Longissimus thoracis* muscle (LT) using a Minolta CM-508c (illuminate: D65, Observer: 10°) on five anatomical positions and the mean was taken as final value. Meat colour was expressed according to the CIE-Lab colour space by reporting L^*, a* and b* values (CIE 1978). The rib was dissected into muscles (rib eye and other muscles), fat and bones. Each fraction was weighted.

A sample of *Longissimus thoracis* was taken for measuring cooking loss percentage, expressed as the ratio of the difference between the weight before and after cooking on the weight before cooking, using 2-cm thick samples sealed in a polyethylene bag and heated in a water bath to an internal temperature of 70 °C for 40 min (Pohlman et al. 1997). Shear force (WBSF) was assessed on the cooked *Longissimus thoracis* samples, measures were obtained on five cylindrical cores of 1.13 cm in diameter taken parallel to muscle fibres. Shear force was measured by a TA-HDi Texture Analyser (Stable Macro System, London, Great Britain) with a Warner-Bratzler shear attachment (10 N load cell, crosshead speed of 2 mm/s) and interpreted using texture expert software (Joseph 1979).

Statistical analysis

All individual data were statistically analysed with the following model using the PROC GLM of SAS (1996):

$$y_{ijkml} = \mu + T_i + S_j + TS_{ij} + P_k + B_l + TB_{il} + e_{ijklm}$$

where y = the experimental observation, μ = overall mean, T = effect of diet treatment ($i = 1, \ldots, 3$); S = effect of sex ($j = 0,1$); TS = interaction between the treatment and the sex; P = effect of pen ($k = 1, \ldots, 12$); B = effect of the dam breed ($i = 1, \ldots, 3$), TB = interaction between treatment and dam breed; and e = residual error. The P effect was used as error line to test the effects of T, G and TG, while e was used as error line to test B and TB. The interaction between the breed of the dam and the sex of the calves has not been included in the final model because in preliminary analysis it resulted not significant for any trait. Data of BW were covariated with the corresponding values at the beginning of the trial, to correct for initial individual differences within pens. According to the objectives of the study, the following orthogonal contrasts were used to evaluate the effects of dam breed: (i) the offspring of the dairy Brown Swiss cows were compared with those from the two dual purpose breeds; (ii) the offspring of the dual purpose Simmental cows were compared with those from the local dual purpose Rendena cows. The same model, without the P, B and TB effects, was used to analyse the data of DMI and feed efficiency (growth rate/DMI) which were recorded on pen basis. In this case, four pen observations for each treatment were used and the error line coincides with the pen effect.

As the interaction between the dam's breed of calves and the diet treatment has never been significant, only the effects of sex and dam breed are presented and discussed in the present study.

Results and discussion

The average performance of the BB crossbred young bulls of the current study for the main *in vivo* traits, given in Table 1 (DMI: 9.17 kg/day and feed efficiency: 0.15 kg/kg) and Table 2 (growth rate: 1.4 kg/day), and for the *post-mortem* traits, given in Table 3 (dressing percentage: 60.0%; muscle score: 4.17; and fatness score: 2.10), were similar to those frequently found with purebred continental beef breeds; only the slaughter and carcase weights were smaller than those often found in European conditions (Alberti et al. 2008; Gallo et al. 2014). The double muscle BB sires when mated to dairy cows they yield crossbreds characterised by very similar growth rate, feed efficiency,

Table 1. Feed intake and efficiency of crossbreds obtained from Belgian Blue sires and Brown Swiss, Simmental and Rendena dams.

Item	Young Bulls	Heifers	p value	Pen RMSE[a]
Dry matter intake, kg/day				
First period	8.13	7.78	.09	0.298
Second period	10.07	9.32	.13	0.747
Entire trial	9.17	8.60	.07	0.456
Feed efficiency,[b] kg/kg of DM				
First period	0.191	0.178	.16	0.0142
Second period	0.141	0.115	.06	0.0192
Entire trial	0.152	0.135	.02	0.0100

[a]Root of mean square error.
[b]Feed efficiency was computed as growth rate/DMI.

Table 2. *In vivo* individual traits of crossbred young bull and heifers obtained from Belgian Blue sires and Brown Swiss (BS), Simmental (Si) and Rendena (Re) dams.

	Sex[1]		Dam breed[2]			Dam breed contrasts		Pen RMSE[3]	Residual RMSE[3]
	Young bulls	Heifers	BS	Si	Re	BS versus (Si + Re)	Si versus Re		
Heads:	24	29	30	12	11				
Body weight, kg:									
Initial	279	269	274	273	274	0.73	0.86	11.6	7.5
Intermediate	418	394	407	403	408	0.88	0.70	23.2	20.9
At slaughter	535^{B}	484^{A}	506	513	509	0.57	0.82	15.0	30.9
Withers height, cm:									
Initial	106.7	105.0	106	105	106	0.17	0.76	3.3	2.3
Intermediate	117.8^{B}	114.4^{A}	117	116	115	<0.01	0.82	2.7	2.4
At slaughter	124.9^{B}	121.4^{A}	124	122	123	<0.01	0.72	2.8	2.2
Muscle score:									
Initial	3.78^{B}	3.13^{A}	3.37	3.61	3.40	0.16	0.12	0.30	0.32
Intermediate	4.15^{B}	3.53^{A}	3.71	3.96	3.85	<0.01	0.29	0.27	0.23
At slaughter	4.37^{B}	4.02^{A}	4.03	4.30	4.25	<0.01	0.69	0.29	0.28
Fatness score:									
Initial	1.00	1.00	1.00	1.00	1.00	–	–	–	–
Intermediate	1.06 ^{A}	1.83 ^{B}	1.52	1.50	1.32	0.22	0.20	0.17	0.33
At slaughter	1.77^{A}	2.76^{B}	2.20	2.33	2.25	0.45	0.65	0.31	0.43
Growth rate, kg/d:									
First period (90 days)	1.55^{b}	1.38^{a}	1.47	1.45	1.49	0.98	0.64	0.19	0.20
Second period (94 days)	1.35^{B}	1.01^{A}	1.16	1.23	1.15	0.64	0.37	0.18	0.22
Total (184 days)	1.40 ^{B}	1.17 ^{A}	1.27	1.29	1.29	0.72	0.97	0.11	0.15

[1]Within row and sex, numbers with different superscripts differ for $^{a,b}p < .05$; $^{A,B}p < .01$.
[2]Dam breeds: Brown Swiss (BS), Simmental (Si) and Rendena (Re).
[3]Root of mean square error.

Table 3. Post-mortem traits of crossbred young bulls and heifers obtained from Belgian Blue sires and Brown Swiss (BS), Simmental (Si) and Rendena (Re) dams.

	Sex[1]		Dam breed[2]			DB contrasts		Pen RMSE[3]	Residual RMSE[3]
	Young bulls	Heifers	BS	Si	Re	BS versus (Si + Re)	Si versus Re		
Carcass traits:									
Weight, kg	313	289	302	296	304	0.77	0.61	17.7	24.8
Dressing, %	60.0^{B}	57.9^{A}	59.1	58.5	59.1	0.44	0.33	1.00	1.30
Conformation score[4]	4.17	4.19	4.04	4.25	4.25	0.02	0.99	0.34	0.31
Fatness score[4]	2.10^{A}	3.00^{B}	2.48	2.58	2.59	0.10	0.94	0.13	0.23
Rib cut weight, g	986$^{\beta}$	901$^{\alpha}$	928	956	947	0.45	0.89	48	110
Rib cut composition, %:									
rib eye	49.5^{b}	44.6^{a}	46.6	48.7	45.6	0.42	0.03	5.4	3.0
other muscles	22.7	23.0	22.8	22.5	23.3	0.77	0.30	3.2	1.8
fat	14.4^{A}	20.6^{B}	17.3	17.2	17.9	0.72	0.60	4.0	3.1
bone	12.4^{b}	10.4^{a}	12.4	10.4	11.5	0.03	0.26	2.6	2.2
Rib eye quality traits:									
pH	5.48	5.44	5.50	5.44	5.45	0.02	0.69	0.12	0.07
drip loss, %	4.60^{a}	6.07^{b}	4.87	5.48	5.65	0.05	0.74	1.46	1.19
cooking loss, %	29.1^{B}	26.7^{A}	28.5	27.4	27.7	0.03	0.70	1.95	1.55
Colour traits[5]									
L*	35.4	36.4	35.9	36.1	35.7	0.90	0.71	3.0	2.0
a*	10.1	10.6	10.0	9.9	11.2	0.20	0.05	1.8	1.5
b*	13.5	14.2	13.7	13.7	14.3	0.30	0.26	1.5	1.2
S	16.9	17.8	17.0	17.0	18.2	0.20	0.09	2.1	1.6
H	53.3	53.4	53.9	54.3	52.0	0.37	0.07	3.1	3.0
WBSF[6], N	35.5^{B}	26.2^{A}	35.6	27.6	29.3	<0.01	0.57	5.2	7.3

[1]Within row and sex, numbers with different superscripts differ for $^{a,b}p < .05$; $^{A,B}p < .01$.
[2]Dam breeds: Brown Swiss (BS), Simmental (Si) and Rendena (Re).
[3]Root of mean square error.
[4]Conformation score was linearly scored from S+ (all muscle profiles extremely convex; exceptional muscle development) to P− (all muscle profiles concave to very concave; very poor muscle development) considering the profiles of shoulders, loins, rump, tights and buttocks. Conformation was transformed in numerical terms: S+ = 6.33, S = 6, S− = 5.66, P+ = 1.33, P = 1.00, P− = 0.66. Fatness was linearly scored considering the presence and the thickness of subcutaneous fat depots at specific points of the body, from 1 (very lean: no palpable fat is detectable, the ribs, the bone structure and the head of the tail are very prominent) to 5 (very fat: thick fat depots are present over the shoulders, the ribs and around the head of the tail, bone structure is no longer visible).
[5]L = Lightness; a* = redness; b* = yellowness; S = saturation index; H = hue angle.
[6]WBSF = Warner Bratzler Shear Force.

dressing percentage and meat quality than crossbred originated from Piemontese sires. Even if the both the sires of these breeds are selected through performance testing of young bulls for growth rate and muscularity (Andersen et al. 1981; Gengler et al. 1995; Albera et al. 2001; Boukha et al. 2011), the dairy farmers prefer the BB for mating their cows because of its better muscle conformation, especially in crossbred heifers (Bittante et al. 2017). The main difference between the two selection strategies is that Piemontese is heavily selected (60% of total selection index) for both direct and maternal ease of calving (Kizilkaya et al. 2003), while BB is not, because almost all the purebred cows of this breed deliver through caesarean section and thus there is not phenotypic variation for these traits in the population (Kolkman et al. 2007).

The effect of sex on the performance of crossbred calves

Remarkable, was the very good performance that characterised the crossbred heifers. Respect to young bulls, heifers consumed daily only 7% less DM, grew only 16% less and were only 11% less efficient in feed conversion. Moreover, at slaughter, the heifers exhibited a dressing of only 2.1 percentage units lower than males and a very similar carcase conformation. This small sexual dimorphism seems to be a peculiarity of the BB breed (Bittante et al. 2017).

Regarding tissue composition, heifers confirmed to be characterised by higher fat covering of the carcase and also of dissectible fatty tissues of the sample joint respect to young bulls (Bittante et al. 2017). Also the quality of the meat was affected by sex, being the rib eye muscles of heifers characterised by higher drip loss, lower cooking loss, similar colour traits and much lower shear force than those of young bulls. The literature on these topics are more controversial (Augustini et al. 1992), probably because of different production systems adopted for males and females to take into account their different lean meat and fat growth potential (Gerhardy 1995).

The comparison of brown Swiss, Simmental and Rendena dam breeds

The comparison between the crossbreds obtained from the dairy cows (BS) and from the cows of the two dual purpose breeds presented some important differences. In contrast, the crossbreds from the two dual purpose maternal breeds (Si and Re) evidenced limited differences. However, this last comparison requires much caution as the small number of crossbreds tested allows to draw only some preliminary indications.

The effect of dam breed was not significant respect to growth rate during neither of the phases of the trial, nor during the whole trial. Nevertheless, the muscle conformation of live animals was affected by dam breed. The calves, of both sexes, sired by BB bulls from BS dams were characterised by being slightly taller than calves born from dual purpose cows, both at the intermediate weight and at the slaughter. The BS crossbred calves exhibited also a smaller muscle score respect to the animals obtained from dual purpose cows. The same was not true for fatness score, which resulted very similar among different dam breeds.

Regarding the influence of breed of dam on carcase traits, a significant effect was shown for the conformation score that, paralleling the *in vivo* muscle score, resulted greater for calves born from both dual purpose cows than for those calved by dairy BS cows. The weight and composition of rib cut joint was similar across maternal breeds, with the only exception represented by the higher incidence of bones in the case of crossbreds from the dairy breed respect to those from the two dual purpose breeds. More important were the differences induced by maternal breed on meat quality traits. The rib eye muscle from dual purpose maternal breeds were, in fact, characterised by a lower pH, a higher drip loss and a lower cooking loss, and especially by a much lower shear force. The only differences between the two dual purpose maternal breeds were noted on the incidence of rib eye (greater in Si compared to Re crossbreds) and in redness index of meat (smaller in Si compared to Re crossbreds).

Differently from Holstein Friesian, very few studies dealt with crossbreeding of dairy and dual purpose cows with beef bulls and no study, at knowledge of the authors, compares different Alpine breeds as maternal breed. Several studies, in contrast, compare these breeds as sire breeds. Among these, Williams et al. (1995) summarised and modelled the results of three cycles of cattle germplasm evaluation comparing 14 cattle breeds to Angus, Hereford and their crosses used as reference. They found that Si crossbreds (from Hereford × Angus cows) out yielded slightly BS calves and also Tarentaise (another dual purpose Alpine local breed) calves in terms of growth rate, but not in terms of carcase composition, maintenance requirements and biological efficiency.

In trials aimed to compare purebred young bulls of the Alpine breeds, in less intensive production systems, Si young bulls exhibited a higher growth rate, but similar slaughter performances, respect to Re (Cozzi et al. 2009) and also respect to BS and original Bruna Alpina young bulls (Bonsembiante et al. 1988; Kögel von et al. 1997).

On the other hand, the differences observed among young bulls and heifers obtained from BS, Si and Re cows mated to BB bulls reflect the differences observed among the purebred cull cows of these three breeds, both in terms of *in vivo* and *post-mortem* traits (Bazzoli et al. 2014; Gallo et al. 2017). It worth also be noted that the new-born calves obtained from this type of crossbreeding in the same Alpine area are characterised by notable differences when sold at local auction. Dal Zotto et al. (2009) observed that that the average price per head of BB crossbred calves is about twice the price of the corresponding purebred calves of the maternal breeds. Among these, the Si calves were not much different from BS ones in terms of age and BW at auction both as purebreds and BB crossbreds, but the former presented higher prices than the latter, and both were superior to calves from Holstein cows. Moreover, the Alpine Grey, another local dual purpose breed, calves were intermediate between Si and BS derived calves.

Conclusions

The use of crossbreds derived from double muscled Belgian Blue as a sire breed and a dairy or a double purpose breed cows is obtaining a renewed interest in the Alps, because of high sale price of crossbred calves in local auctions, with respect to the pure breed counterparts. This gives the opportunity of increasing the incomes of many dairy farms in the Alps region. In this work, it was observed that when the double muscled Belgian Blue is used as paternal breed, the maternal breed has influence on some carcase and meat quality traits, and minor influences on growth performance. The major differences among maternal breed were about the comparison between Brown Swiss and two dual purpose breeds (Simmental and Rendena), where no differences between Si and Re were observed.

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Disclosure statement

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