Italian Journal of Animal Science

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tjas20

Beef quality in two autochthonous Valdostana breeds fattened in alpine transhumance: effect of lowland finishing and meat ageing

Michael Kreuzer, Steve Pervier, Germano Turille, Maria Karpatcheva, Nina Julius, Corrado Oreiller & Joel Berard

To cite this article: Michael Kreuzer, Steve Pervier, Germano Turille, Maria Karpatcheva, Nina Julius, Corrado Oreiller & Joel Berard (2021) Beef quality in two autochthonous Valdostana breeds fattened in alpine transhumance: effect of lowland finishing and meat ageing, Italian Journal of Animal Science, 20:1, 267-278, DOI: 10.1080/1828051X.2021.1882346

To link to this article: https://doi.org/10.1080/1828051X.2021.1882346

Published online: 09 Feb 2021.

ITALIAN JOURNAL OF ANIMAL SCIENCE
2021, VOL. 20, NO. 1, 267–278
https://doi.org/10.1080/1828051X.2021.1882346

Taylor & Francis
Taylor & Francis Group

PAPER

OPEN ACCESS Check for updates

Beef quality in two autochthonous Valdostana breeds fattened in alpine transhumance: effect of lowland finishing and meat ageing

Michael Kreuzer[a], Steve Pervier[a,b], Germano Turille[b], Maria Karpatcheva[c], Nina Julius[d], Corrado Oreiller[e] and Joel Berard[f]

[a]Institute of Agricultural Sciences, ETH Zurich, Zürich, Switzerland; [b]Institut Agricole Régional, Settore Zootecnia, Aosta, Italy; [c]Institute for Environmental Decisions, ETH Zurich, Zürich, Switzerland; [d]School of Life Sciences und Facility Management, ZHAW, Wädenswil, Switzerland; [e]Fondazione per la Formazione Professionale Turistica, Châtillon, Italy; [f]Forschungsbereich Produktionssysteme Tiere und Tiergesundheit, Agroscope, Posieux, Switzerland

ABSTRACT

European consumers demand locally produced meat, preferably from regional breeds, but meat quality is unknown. Heifers from two dual-purpose breeds, Valdostana Chestnut (VC) and Valdostana Red Pied (VR), autochthonous to the Aosta valley, were compared with Piedmontese (PI), a beef breed. Fourteen VC and VR each grazed high alpine pastures, and ten PI received fresh grass in a lowland barn. In each group, the heavier half of the animals were slaughtered after the grass-feeding period. All others received hay and concentrate for another 48 days. Properties of the carcase and the *longissimus thoracis* (LT) and *biceps femoris* (BF) muscles (aged 7 or 28 days) were determined. Sensory analysis of the LT and BF muscles was performed by 10 trained panellists and 53 consumers, respectively. The VC and VR grew faster than the PI, but dressing percentages and conformation scores were inferior. The LT was perceived as less tender from the VC and VR compared to the PI, and shear force and insoluble collagen were also higher. Finishing accentuated the problem for VC and did not improve carcase and meat quality otherwise. Prolonged ageing did not render the beef more tender. Compared to the LT, the BF was more resistant to factors of influence in quality. Consumers perceived long-aged beef to be preferable and comparably inexpensive for its quality. No other factor influenced sensory impression. In conclusion, the LT and, less so, the BF from the autochthonous breeds were not fully competitive in quality with those of the beef breed.

HIGHLIGHTS

- Grass-fed autochthonous Valdostana breeds were compared with Piedmontese cattle.
- Valdostana heifers performed better but were inferior in dressing percentage and carcase conformation.
- The beef from the Valdostana breeds was less tender than that from the Piedmontese.

ARTICLE HISTORY
Received 26 September 2020
Revised 11 January 2021
Accepted 23 January 2021

KEYWORDS
Valdostana Chestnut; Valdostana Red Pied; Piedmontese; meat quality; growth performance

Introduction

Extensive livestock farming contributes significantly to the preservation of alpine landscapes (Gellrich et al. 2007; Cocca et al. 2012). The specific composition of the alpine vegetation is the basis for providing meat with particular properties because it is rich in plant secondary compounds. These compounds may at least partially protect valuable polyunsaturated fatty acids from biohydrogenation processes in the rumen (Khiaosa-Ard et al. 2011), and thus they may be transferred to the meat (Ådnøy et al. 2005; Gangnat et al. 2016). However, when marketing such meat through common channels, these benefits provided by alpine grazing and the extra management efforts required to produce such beef are not compensated for by a higher price (García-Martínez et al. 2011). Extensive beef production systems might therefore be valorised when building on the consumers' increasing valuation of foods from known geographic origins.

Valdostana Chestnut (VC) and Valdostana Red Pied (VR) are two dual-purpose breeds autochthonous to the alpine region of North-West Italy (Aosta Valley). The VC, like their breed companion the Valdostana Black Pied, is classified as *Bos taurus brachyceros*

CONTACT Dr. Joel Berard joel.berard@agroscope.admin.ch Forschungsbereich Produktionssysteme Tiere und Tiergesundheit, AgroscopeRoute de la Tioleyre 4, CH-1725 Posieux, Switzerland

(Ritchie 2009; Sartori and Mantovani 2010). The VR instead is related to the ancient *Bos taurus frontosus*, the precursor of many Red Pied breeds in Europe, such as Simmental (Preiswerk and Crettaz 1986). Both VC and VR are characterised by comparably low body weight (BW) and muscular appearance. Therefore, they are particularly suitable for harsh alpine conditions. Beef from VC and VR is indeed mainly produced during alpine summer grazing. One constraint is that, despite being bred for dual purposes, the breeding emphasis is on milk production, which is antagonistic to growth performance (Mazza et al. 2015). Additionally, Aosta valley consumers tend to link VC and VR beef with off-flavours and low tenderness. No scientific investigation is known to the authors that describes the two local Valdostana breeds in terms of growth, carcase and meat quality and compares them with other breeds.

Further measures might increase the competitiveness of such alpine production systems. Intensive finishing in the lowlands might trigger compensatory growth (Yambayamba et al. 1996; Gangnat et al. 2016), and prolonged ageing of the beef might tenderise the meat considered inherently tough. However, ageing is only successful when toughness is due to unfavourable myofibrillar properties and less so when connective tissue properties are limiting (Campo et al. 2000). Also, long ageing periods enhance the risk of meat discolouration, which is especially critical as pastured beef is already susceptible to discolouration by grass feeding and alpine sojourn (Velik et al. 2013; Gangnat et al. 2016), a phenomenon possibly counteracted by finishing on other types of feed.

The aim of the present study was, therefore, to test the following hypotheses. (1) There is a difference in performance, carcase and meat quality between VC and VR, the two Valdostana breeds. (2) Lowland finishing in addition to alpine grazing will lead to carcases with desired conformation and fat cover but will also affect beef sensory properties. (3) An inferior tenderness of the beef can be counteracted by prolonged ageing. (4) Consumers position beef differently with respect to price worthiness by considering the breed and the beef finishing and ageing. (5) Piedmontese (PI), autochthonous to North-West Italy and competitive in carcase and meat quality to other beef breeds (Chambaz et al. 2001), is superior to VC and VR in performance and meat quality even when fed grass-based diets, but in the lowlands.

Materials and methods

Experimental animals and husbandry

All animal-related procedures were in compliance with EU Directive 2010/63/E.U. A total of 38 heifers (14 VR, 14 VC and 10 PI) born between October 2014 and January 2015 were included in this study. Until the experiment started in May 2015, all animals remained with their owners and were kept indoors in groups and received hay and some concentrate. At the start of the experiment, the VC and VR were gathered and kept for about 2 weeks in the same barn at 575 m a.s.l.; they received hay and fresh grass (Figure 1). They were then moved to pasture at 1500 m a.s.l. and 6 weeks later to a pasture covering a range from 2300 to 2600 m a.s.l. No supplementary feeds except NaCl

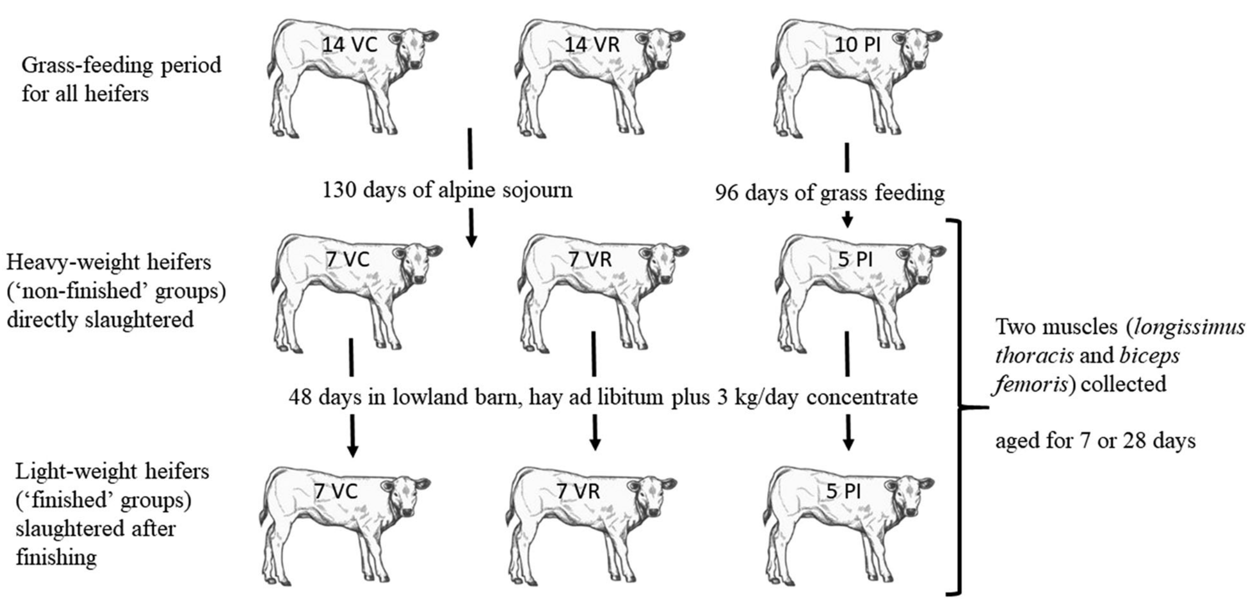

Figure 1. Experimental design and schedule. VC: Valdostana Chestnut; VR: Valdostana Red Pied; PI: Piedmontese.

were provided. The PI was gathered in June 2015, kept separate in quarantine, and also received hay and fresh grass for 2 weeks. Due to their very animated behaviour, the PI could not be kept on pasture and therefore remained in group housing at 575 m a.s.l. and were fed fresh-cut grass exclusively. Freshwater was accessible at any time.

In September 2015, after 130 days of alpine sojourn (VC and VR) or 96 days of grass-feeding (PI), all animals per breed with a BW above average were slaughtered ('non-finished' groups). The 'finished' groups were kept for another 48 days in the lowland barn and were given *ad libitum* access to local hay and 3 kg commercial concentrate daily via an automatic feeder six times/day. The concentrate consisted per kg of 462 g corn, 135 g wheat bran, 90 g soybean meal, 90 g barley, 90 g sugar beet pulp, 80 g sunflower meal, 30 g sugar cane molasses, 10 g sodium bicarbonate, 5 g mineral mix, 3 g sodium chloride and 5 g *Saccharomyces cerevisiae*. The contents stated by the producer (VI. M srl. Quart -AO- Italy) were per kg 870 g dry matter, 145 g crude protein, 29 g fat 2.9% and 45 g crude fibre. This principle, of finishing only the light-weight cattle to reach the same slaughter weight as the heavy-weight cattle, has previously been applied in experimental research in beef animals (Gangnat et al. 2016) and reflects the farmers' likely reaction when removing cattle from alpine pastures.

The animals were weighed with a cattle balance with an accuracy of ±1 kg at the start of the experiment and at the end of the grass-feeding and finishing periods ('finished' group only) after being fasted for 4 h.

Slaughter, carcase evaluation and meat sampling

The animals were stunned by a captive bolt pistol at a local slaughterhouse. Weights of the carcase, liver, lungs, heart, kidneys and spleen were determined 30 min post mortem (p.m.). Carcase conformation and fat cover, applying the EUROP grading system, were assessed by an independent professional. Ultimate pH was determined at 24 h p.m. in the *longissimus thoracis* (LT) and *biceps femoris* (BF) muscles, two valuable cuts. From the right carcase side, samples of the LT were obtained between the 6th and 8th rib, and those of the BF were harvested at 4–12 cm from the proximal to the distal part of the muscle. Vacuum-sealed in plastic bags, similarly-sized muscle portions were aged at 2 °C for either 7 or 28 days. After being removed from the bags and dried with a paper towel, ageing loss was recorded. One part was analysed for physicochemical properties, and the other part was stored at −20 °C for later sensory analysis.

Physicochemical meat analysis

Meat slices (1 cm thick) were weighed and hung freely on an anchor for 24 h in a plastic bag at 4 °C. Drip loss was assessed 24 h later (Honikel 1998). CIE L*a*b colour space was measured on a fresh cut meat slice being bloomed for 1 h in the dark at 4 °C on five points per slice, using a Chroma metre (model 300-CR, Minolta, Dietikon, Switzerland, with D65 as the light source). Slices 3 cm thick were heated to 71 °C core temperature on a clamshell grill (model Turmix 246, Beer Grill, Zurich, Switzerland) at 195 ± 10 °C plate temperature. Weight differences were used to calculate cooking loss before the meat was chilled at 4 °C overnight. Afterwards, 7–15 cylinders of 1.27 cm diameter were punched out along the direction of the muscle fibres with a round knife mounted on a drilling machine. They were cut perpendicular to the fibre direction using a Warner–Bratzler shear device (Zwick Roell Z005, Zwick Roell AG, Ulm, Germany, with its software testXpert II, Version 3.61) with a load cell of 5 kg, a shear plate thickness of 3 mm and cross-head speeds of 400 mm/min. The values obtained per piece of meat were averaged.

Homogenised samples of the non-aged LT were analysed for intramuscular fat content (IMF). This was determined after 30 min of hydrolysis with 4 M HCl on a Hydrolysis Unit B-425 (Büchi, Flawil, Switzerland) and extraction with petrol ether in a Soxhlet apparatus B-811 (Büchi) following AOAC (2006) index no. 963.15. Collagen contents were determined by multiplying hydroxyproline by 8 (AOAC 2009; index no. 990.26), measured at a wavelength of 560 nm (UV-Vis spectrophotometer, VWR UV-6300, VWR International, Radnor, PA, USA). To determine insoluble hydroxyproline, and from that the solubility of collagen, homogenised samples were first heated for 70 min at 77 °C and then centrifuged for 15 min at 2300 × *g* following Liu et al. (1996).

Sensory panel analysis

A descriptive sensory analysis was conducted with ten experienced Italian assessors (49–67 years of age) over 12 sessions. Each panellist analysed one LT sample per treatment (12 total samples; 3 breeds × 2 finishes × 2 ageing treatments) during four 2-h sessions. Each session included one warm-up sample, one blind sample and 12 meat samples in randomised order. Each meat sample consisted of three cubes of meat. The meat was thawed from −20 °C to 9 °C over 22 h and grilled shortly before the session following the protocol described above. Then, 3 mm of the meat's grilled surfaces were removed and the meat steak cut into cubes of 16 mm side lengths. Samples were served on preheated ceramic plates covered with ceramic cups. Sensory booths kept at room temperature and under normal fluorescent illumination (source of daylight K 6500) were used. The evaluation was conducted using Fizz for Windows 2.47B software (Biosystèmes, Couternon, France). Groups of attributes evaluated included smell, taste and aftertaste texture and were judged on an unstructured line scale ranging from 'absent' (0) to 'intense' (100). Descriptions for texture attributes were from 'soft' to 'firm' (hardness), from 'not juicy' to 'juicy' (juiciness), from 'tough' to 'very tender' (tenderness) and from 'fine-fibered' to 'bold-fibered, ball of fibres' (coarseness).

Consumer test

Fifty-three inhabitants of the Aosta Valley region (Italy) aged between 18 and 75 years were placed around big tables to participate in one 2-h session in a sun illuminated hall. No talking was allowed. Initially, the participants answered 17 questions regarding their meat consumption habits. It was found that the majority consumed beef two to three times per week, and other types of meat two to three times per week. Before the session, the frozen BF was thawed at 4 °C over 48 h. Then, the BF was cut into pieces of 2.5 × 4 × 2.5 cm and cooked for 6 min at 200 °C using a convection oven with a fan operating at half speed (model 240201, Zanussi, Pordenone, Italy). Each participant received 11 samples (i.e. one per treatment; except 28-day aged meat from finished VR due to lack of material). The samples (two to three pieces per person) were served sequentially at about 45 °C on pre-warmed plates and in randomised order. Salt and spices were omitted. Three-digit codes were applied for characterising samples to prevent influencing or confounding information. Attributes included overall liking and liking of taste, juiciness, tenderness and aftertaste. Participants were asked if they considered the respective meat sample tested to be too expensive or very inexpensive if it cost €11/kg (reference price). For this, they had to hypothetically assume that this meat would be of generic origin, from local origin or local origin plus a local breed. Seven-point hedonic scales were used throughout.

Statistical analysis

Data were analysed by analysis of variance using the Mixed procedure of SAS (version 9.3, SAS Institute Inc., Cary, NC). The model used for growth and slaughter performance and non-aged meat data included breed, finishing and their interaction as fixed effects and animal as a random effect. For all other meat properties ageing period, the two-way interaction of ageing period with the breed and with finishing, as well as the three-way interaction was included as fixed effects in addition. The two significant cases of three-way interactions are reported in a footnote to the tables. The Tukey–Kramer method was applied for multiple comparisons among breed means and breed × finishing interaction means (not shown in table). Significance was assumed at $p < .05$, $p < .10$ was considered a trend.

For the sensory evaluation, effects considered included breed, finishing, ageing, breed × finishing and breed × ageing as fixed effects (Tukey–Kramer for interactions), and assessor and replication as random effects. Raw data underwent counting of outliers (3.8% of all data points), which were defined as data points deviating from the mean by more than two standard deviations. Panel performance was judged using SenPAQ (version 5.0, QiStatistics; www.qistatistics.co.uk/product/senpaq).

Results

Growth and slaughter performance

In all breeds, the animals of the finished groups were included in the study at significantly earlier average ages than the non-finished group, resulting in approximately the same age at slaughter (Table 1). The same is true for the significantly different starting BWs vs. the similar slaughter and carcase weights. The two autochthonous breeds did not differ in growth performance. They were always significantly lighter than the PI during the grass-feeding period but had significantly higher average daily gains. A trend for lower BW gains of the PI vs. the VC and VR in the finishing period remained. Dressing percentage was significantly higher in the PI vs. the VC and VR, whereas finishing had no clear effect. This accentuated differences between the PI and VC/VR in carcase weight even more than the BW difference. The PI carcases had significantly higher conformation scores than those of the VC and VR. The fat cover score was very low in all breeds. It was significantly increased by finishing, but this was apparent only in the VC and VR.

Table 1. Effect of dual-purpose Valdostana (Chestnut and Red Pied) and beef (Piedmontese) breeds (B) as well as 48 days of finishing (F) on growth and slaughter performance.

Breed	Chestnut		Red Pied		Piedmontese			*p*-Values		
Finishing	No	Yes	No	Yes	No	Yes	SEM	B	F	B × F
Animals, *n*	7	7	7	7	5	5				
Age, days										
Start	192	176	181	154	267	214	10.40	.001	<.001	.280
At slaughter	322	354	311	332	363	358	12.30	.010	.080	.280
Body weight, kg										
Start	147	120	158	127	264	210	10.50	<.001	<.001	.350
End of grass feeding	195	158	197	169	264	204	10.60	<.001	<.001	.270
At slaughter	195	202	197	210	264	232	11.90	<.001	.644	.110
Body weight gains, g/day										
Start to end of grass feeding	368	290	299	320	4	−65	324.30	<.001	.090	.160
Finishing phase		911		863		588	110.70	.090		
Dressing percentage	48.80	45.30	47.30	46.20	52.20	52.80	0.92	<.001	.072	.059
Carcase weight, kg	95	92	91	95	138	123	7.50	<.001	.382	.390
Carcase characteristics[a]										
Conformation score	1.71	1.57	1.71	1.86	3.20	3.00	0.25	<.001	.722	.715
Fat cover score	1.00	1.43	1.00	1.43	1.00	1.00	0.15	.222	.012	.222
Organ proportions, g/kg body weight										
Liver	11.80	12.9	11.50	13.40	9.30	11.70	0.46	<.001	<.001	.297
Lungs	6.12	7.42	6.29	6.95	5.73	6.84	0.32	.269	<.001	.493
Heart	4.32	4.12	4.26	4.25	3.42	3.78	0.20	.002	.741	.321
Kidneys	2.29	2.43	2.16	2.52	1.57	1.81	0.15	<.001	.030	.654
Spleen	1.85	2.03	1.79	1.66	1.54	1.67	0.12	.011	.452	.291

Values are Least Square means, standard errors of the means (SEM) and *p*-values.
[a]According to the EUROP carcase grading system: conformation, P = 1 = poor to E = 5 = very pronounced; fat cover, 1 = carcase not covered with fat tissue, 5 = carcase excessively fat, 3 = carcase homogenously covered with fat tissue.

Table 2. Effect of dual-purpose Valdostana (Chestnut and Red Pied) and beef (Piedmontese) breeds (B), 48 days of finishing (F) as well as ageing (A) for 7 or 28 days on the physicochemical properties of the *longissimus thoracis* muscle.

Breed		Chestnut		Red Pied		Piedmontese			*p*-Values					
Finishing		No	Yes	No	Yes	No	Yes	SEM	B	F	A	B × F	B × A	F × A
Animals, *n*	A	7	7	7	7	5	5							
$pH_{24\,h\ p.m.}$		5.56	5.60	5.62	5.83	5.65	5.74	0.06	.667	<.001		.342		
Fat, g/kg meat	a	6.43	12.43	7.57	9.57	3.56	7.79	1.07	.002	<.001		.101		
Collagen content, g/kg meat														
Total		4.11	4.36	4.89	4.28	3.54	3.79	0.35	.016	.869		.215		
Insoluble		3.65	3.69	4.32	3.19	2.80	2.70	0.32	.003	.084		.055		
Solubility, %		11.50	14.90	11.3	24.40	19.8	29.20	5.97	.112	.042		.572		
Drip loss, 24 h, %	7	1.37	1.51	1.45	1.63	1.30	1.51	0.19	.995	.838	.013	.970	.506	.122
	28	1.29	1.15	1.16	1.09	1.37	1.18							
Ageing loss, %	7	2.26	3.02	2.29	3.11	1.47	2.20	0.55	.664	<.001	<.001	.845	.125	.176
	28	3.50	4.75	3.72	4.94	3.61	5.59							
Cooking loss, %	7	23.30	24.00	22.10	24.20	20.4	25.10	1.42	.064	.127	.070	.161	.023	.071
	28	24.20	24.50	23.50	20.90	26.1	27.90							
Colour														
Lightness (L*)	7	36.50	36.70	39.40	35.80	37.90	39.10	0.84	.007	.919	.807	.002	.874	.120
	28	36.50	36.90	37.70	36.80	37.20	39.60							
Redness (a*)	7	18.50	15.50	18.40	15.50	16.50	15.40	0.52	.006	<.001	.001	.188	.238	.015
	28	18.80	17.90	18.00	16.70	17.50	16.70							
Yellowness (b*)	7	0.34	−0.08	−0.38	−0.26	0.01	1.12	0.45	.112	.366	<.001	.078	.455	.043
	28	2.53	1.73	2.33	0.96	1.84	1.92							
Hue	7	0.02	−0.01	−0.02	−0.03	0.00	0.07	0.03	.094	.458	<.001	.074	.559	.106
	28	0.13	0.10	0.13	0.05	0.10	0.11							
Shear force, N	7	54.40	77.60	53.50	72.30	42.70	47.30	6.37	.001	<.001	.481	.065	.119	.975
	28	48.50	78.20	49.80	54.20	45.00	58.10							

Values are Least Square means, standard errors of the means (SEM) and *p*-values.
[a]In the non-aged meat.

The inner organs, except lungs, made up a significantly lower proportion of BW in the PI vs. the VC and VR. Finishing significantly enhanced the weights of the liver, lungs and kidneys. No significant breed × finishing interaction was found in growth and slaughter performance.

Physicochemical meat properties

The ultimate pH was significantly higher in the finished compared to the non-finished heifers in the LT (Table 2) and the BF (Table 3). Still, the pH of individual animals never exceeded 6.2 (data not shown).

Table 3. Effect of dual-purpose Valdostana (Chestnut and Red Pied) and beef (Piedmontese) breeds (B), 48 days of finishing (F) as well as ageing ageing (A) for 7 or 28 days on the physicochemical properties of the *biceps femoris* muscle.

Breed		Chestnut		Red Pied		Piedmontese			*p*-Values					
Finishing		No	Yes	No	Yes	No	Yes	SEM	B	F	A	B × F	B × A	F × A
Animals, *n*	A	7	7	7	7	5	5							
$pH_{24\,h\ p.m.}$		5.55	5.75	5.41	5.73	5.54	5.80	0.049	.076	<.001		.345		
Drip loss, 24 h, %	7	1.21	1.13	0.89	1.28	2.02	1.53	0.214	.034	.625	.023	.153	.011	.283
	28	1.16	1.17	0.97	1.21	0.95	1.18							
Ageing loss, %	7	2.62	1.67	1.88	2.03	3.15	2.09	0.498	.280	.773	.251	.132	.259	.024
	28	2.04	2.25	2.24	3.28	2.55	2.75							
Cooking loss, %	7	21.30	27.30	20.20	26.10	22.40	26.20	1.340	.271	.007	.637	.692	.906	<.001
	28	24.80	23.80	24.70	21.10	23.30	23.80							
Colour														
Lightness (L*)	7	35.70	36.50	37.70	37.50	40.20	38.10	0.730	<.001	.123	<.001	.667	.442	.003
	28	37.70	38.30	38.40	40.60	41.00	43.40							
Redness (a*)	7	18.70	19.90	18.60	19.00	18.20	16.60	0.550	.001	.699	.001	.041	.313	.712
	28	19.70	20.40	19.20	19.50	19.20	18.90							
Yellow-ness (b*)	7	−0.61	2.09	−0.24	1.92	0.27	0.99	0.430	.113	<.001	<.001	.162	.037	.001
	28	3.56	3.59	3.43	4.26	4.76	4.97							
Hue	7	−0.03	0.10	−0.01	0.10	0.02	0.06	0.021	.029	<.001	<.001	.222	.038	.001
	28	0.18	0.17	0.18	0.22	0.24	0.26							
Shear force, N	7	39.90	47.40	39.60	42.00	34.10	35.90	3.350	.141	.056	.880	.704	.149	.774
	28	37.80	40.40	39.90	40.90	36.70	41.70							

Values are Least Square means, standard errors of the means (SEM) and *p*-values.

There were only minor breed effects on pH and no interaction with finishing. The IMF in the LT was similar in the VR and VC, but significantly lower in the PI (9.43 and 8.57 vs. 5.67 g/kg, respectively) (Table 2). The LT of the PI had significantly lower total and insoluble collagen content than that of the VR and VC. Water-holding capacity, as measured by different types of losses, was mostly unaffected by breed in the LT (Table 2) and BF (Table 3). There was a trend for breed differences in cooking loss of the LT, and drip loss was significantly higher in the BF of PI vs. VR and VC heifers. Finishing significantly increased ageing loss in the LT and cooking loss in the BF. Prolonged ageing significantly reduced drip loss in both muscles and increased ageing loss (and cooking loss in trend) in the LT but not the BF. There were significant interactions of breed × ageing in cooking loss (LT) and drip loss (BF), and finishing × ageing in ageing and cooking loss (BF). The LT of the VC was the darkest and reddest of all breeds in both muscles (significantly to the PI). The LT was less red in the finished heifers and it was more red and yellow with a significantly higher hue when aged longer. The ageing effect was similar for the BF, which at the same time became significantly lighter. There were significant finishing × ageing interactions in redness and yellowness (LT) and lightness, yellowness and hue (BF). In addition, breed × ageing significantly interacted in yellowness and hue (BF), and breed × finishing in lightness (LT) and redness (BF). Shear force in the LT of the VC was significantly higher than that in the LT of the PI, and was intermediate in the LT of the VR. In both the VC and VR samples, shear force was significantly higher in the non-finished animals (VC: 51 N and VR: 52 N vs. PI: 44 N). By finishing, shear force differences were even more pronounced in the VC (78 N), but less so in the VR (63 N) and PI (53 N) (trend of breed × finishing interaction). Finishing significantly increased the shear force of the LT. No breed effects, and only a trend for finishing effects, were found in the BF shear force. A longer ageing period did not affect shear force.

Sensory evaluation of the meat

Panellists reported significant breed differences in all attributes describing LT texture (Table 4). The PI beef was significantly softer, juicier, more tender and less coarse than the VR beef, which in turn was significantly superior to the VC beef. Panellists were unable to distinguish between breed in the attributes describing smell, taste (except in sweetness) and aftertaste. There was a significantly less pronounced barny smell of the LT of finished heifers, and impressions of bloody smell and taste and of metallic smell and aftertaste were significantly weaker. On average across all breeds, sweet taste was significantly more pronounced and sour taste less pronounced with finishing. Finishing also made the LT significantly tougher, less juicy, less tender and coarser; this, however, varied greatly among breeds. Prolonged ageing significantly enhanced barny smell and taste and sour taste. Ageing did not affect the texture impression of the meat. The breed × finishing interaction was significant with the metallic smell, sweet taste and all texture

Table 4. Effect of dual-purpose Valdostana (Chestnut and Red Pied) and beef (Piedmontese) breeds (B), 48 days of finishing (F) as well as ageing (A) for 7 or 28 days on the perception of a trained sensory panel of different attributes[a] of the *longissimus thoracis* muscle.

Breed		Chestnut		Red Pied		Piedmontese			*p*-Values					
Finishing		No	Yes	No	Yes	No	Yes	SEM	B	F	A	B × F	B × A	F × A
Animals, *n*	A	7	7	7	7	5	5							
Smell														
Barny	7	37	29	27	31	33	26	4.8	.460	.046	.042	.136	.141	.399
	28	30	34	39	32	54	32							
Bloody	7	28	18	16	21	25	20	4.8	.470	.049	.705	.477	.464	.362
	28	20	19	27	18	34	18							
Brothy	7	29	31	30	29	27	23	2.9	.352	.546	.647	.442	.372	.261
	28	25	32	27	25	25	30							
Metallic	7	18	20	20	19	19	12	2.0	.430	.208	.014	.033	.007	.640
	28	18	21	19	19	29	23							
Taste														
Barny	7	27	25	23	26	23	23	3.6	.931	.570	.026	.044	.307	.596
	28	25	30	27	33	42	23							
Bloody	7	27	19	28	19	32	20	5.1	.106	.003	.996	.409	.412	.891
	28	23	18	26	17	39	22							
Brothy	7	39	36	35	29	46	35	3.3	.088	.749	.603	.502	.453	.010
	28	32	40	35	39	38	42							
Metallic	7	33	32	31	26	35	26	3.8	.443	<.001	.277	.549	.711	.125
	28	37	27	39	23	38	30							
Sour	7	15	16	17	14	18	17	1.9	.097	.036	.027	.475	.643	.122
	28	20	17	19	14	24	18							
Sweet	7	12	15	12	16	18	14	1.1	.014	.021	.993	.009	.083	.214
	28	10	14	15	18	15	15							
Aftertaste														
Astringent	7	17	20	24	20	25	21	2.8	.915	.327	.173	.104	.041	.841
	28	25	27	22	21	25	19							
Brothy	7	24	17	21	20	24	21	2.5	.153	.552	.164	.392	.509	.104
	28	22	26	18	23	28	25							
Metallic	7	22	25	30	24	27	23	2.3	.275	.010	.294	.153	.699	.195
	28	31	20	32	22	27	29							
Texture														
Coarse	7	55	85	61	63	36	45	5.0	<.001	.011	.297	.049	.587	.110
	28	66	67	59	52	33	50							
Hard[b]	7	51	77	50	56	24	39	4.7	<.001	<.001	.397	.048	.451	.285
	28	64	65	46	45	18	45							
Juicy	7	45	25	50	46	78	47	4.8	<.001	<.001	.147	.001	.623	.158
	28	34	29	38	43	77	45							
Tender[b]	7	41	19	41	39	65	50	6.3	<.001	.003	.648	.040	.931	.705
	28	29	31	43	41	76	44							

Values are Least Square means, standard errors of the means (SEM) and *p*-values.
[a]0 = was not noticed at all, to 100 = extremely pronounced; [b]Three-way interaction significant at $p < .05$.

attributes. In general, finishing improved the texture attributes 'course' and 'hard' and worsened those of juiciness and tenderness in the VC and PI, but not in the VR. Breed and ageing significantly interacted only in metallic smell and astringent aftertaste. Likewise, finishing × ageing interactions were rare (exception: brothy taste). A significant three-way interaction was found only in hardness and tenderness impressions of the LT.

The consumers could not distinguish between breeds in overall liking, taste, juiciness, tenderness and aftertaste of the BF (Table 5). Overall, finishing was considered significantly unfavourable concerning liking of taste and juiciness. Prolonged ageing led to significant improvements in overall liking, taste and tenderness. There was a significant breed × ageing interaction in the aftertaste. No interaction between finishing and ageing was found. The appropriateness of the given price for the meat tested was not influenced by breed. Finishing resulted in a trend whereby the consumers stated that the beef was overpriced. Prolonged ageing led the consumers to state that the meat was comparably cheap for its quality. There were no interactions in price appropriateness.

Discussion

The present study aimed to determine differences in performance, carcase and meat quality between grass-fed autochthonous dual-purpose breeds (Valdostana Chestnut, VC and Valdostana Red Pied, VR) common to the geographical area of the study. There was a special emphasis on determining whether limitations can be overcome, in individual or all breeds, by

Table 5. Effect of dual-purpose Valdostana (Chestnut and Red Pied) and beef (Piedmontese) breeds (B), 48 days of finishing (F) as well as ageing (A) for 7 or 28 days concerning consumer perception of sensory attributes and price of *biceps femoris* muscle.

Breed		Chestnut		Red Pied		Piedmontese			*p*-Values					
Finishing		No	Yes	No	Yes	No	Yes	SEM	B	F	A	B × F	B × A	F × A
Animals, *n*	A	7	7	7	7	5	5							
Sensory attributes[a]														
Overall liking	7	4.9	4.3	5.2	4.9	4.8	4.8	0.358	.776	.084	.020	.985	.083	.888
	28	5.4	5.4	[b]	4.7	5.7	5.0							
Taste	7	4.6	4.6	5.9	4.8	4.6	4.8	0.447	.123	.010	.026	.109	.743	.256
	28	5.4	5.1		4.8	5.5	5.0							
Juiciness	7	5.2	3.5	5.5	4.7	4.4	4.8	0.493	.672	.020	.165	.250	.067	.388
	28	5.2	5.0		4.3	5.6	5.0							
Tenderness	7	4.9	3.1	4.9	4.4	4.3	4.7	0.540	.230	.059	.023	.221	.054	.411
	28	5.3	5.0		4.2	5.8	5.1							
Aftertaste	7	4.2	3.9	4.8	4.7	4.1	4.5	0.372	.763	.574	.201	.869	.038	.773
	28	4.7	4.7		4.1	4.9	4.6							
Price[c]														
Generic	7	4.3	3.5	4.6	4.2	4.2	4.3	0.394	.583	.051	.016	.933	.188	.774
	28	4.8	4.7		4.2	5.2	4.5							
Locally reared	7	4.2	3.4	4.5	4.0	4.0	4.1	0.356	.488	.065	.003	.814	.224	.490
	28	4.6	4.6		4.2	4.9	4.5							
Locally reared and local breed	7	4.7	3.9	4.8	4.5	4.6	4.8	0.413	.630	.107	.031	.954	.309	.817
	28	5.1	5.1		4.6	5.4	4.7							

Values are Least Square means, standard errors of the means (SEM) and *p*-values.
[a]1 = low/weak to 7 = high/pronounced.
[b]No data available.
[c]1 = too expensive, 4 = adequate, 7 = very cheap, assuming a price of €11 per kg for the respective meat tested when it would be of generic origin or from local breeds or from local breeds and origin.

finishing treatment after the grass-feeding period and in which breeds ageing can enhance meat tenderness. Accordingly, first, the effects of the main factors of influence are discussed, and then the interactions among these factors are addressed.

Differences between breeds

Conformation scores (muscularity), dressing percentages and organ proportions of the PI were more favourable than those of the VC and VR. Valdostana breed selection focuses on milk production, which has a negative genetic correlation with meat accretion (Mazza et al. 2015). The higher slaughter weights of the non-finished PI compared to the VC and VR are misleading because the PI did not actually grow at all during the grass-feeding period; the higher slaughter weights were a consequence of higher starting BW. This illustrates that the PI cannot gain energy with such a diet; rather, they just cover maintenance requirements. Across the measured traits (i.e. by physicochemical properties, panel assessment and consumer sensory analysis), there were only some differences between the VC and VR vs. the beef breed. The differences in meat colour found were not fully consistent in the two muscles. The PI meat appeared to have a slightly lower water-holding capacity, and its LT had a lower IMF. These slight disadvantages were likely more than compensated for by the lower shear force and content of insoluble collagen of the inherently less tender muscle, the LT, in the PI compared to the dual-purpose breeds. Chambaz et al. (2001) found LT from PI to have a particularly low shear force, low collagen content and high collagen solubility. The present findings align with this report: the trained panel detected a preferable texture, including tenderness, in the PI. Also, Monsón et al. (2004) found a better beef texture in specialised beef breeds than in dual-purpose breeds. It is unlikely that these differences between the PI and VC/VR resulted from the more strenuous grazing at a high altitude of the latter breeds. Beef from calves kept on steep alpine pastures had the same (for LT) or even a lower (for BF) shear force than that from calves grazing flat alpine pastures (Gangnat et al. 2017). Neither the sensory panel nor consumers associated an uncommon smell or taste with the VC or VR beef, and the consumer panel did not find beef origin to be relevant for price differences. The existing misconception common among Aosta valley consumers, therefore, needs to be counteracted by appropriate communication.

Despite their similar body shape, the VC and VR breeds have been developed separately. Still, as hypothesised, the two Valdostana breeds differed much less in carcase and meat quality than they differed from the PI. Clear differences were found, though, with LT texture being superior in the VR compared to the VC. This coincided with a non-significantly lower shear force.

Effects of finishing of the cattle

A finishing period of 48 days was selected. This period was intended to be long enough to compensate for the low energy density of the grass and short enough to still preserve the positive effects of the grass feeding on beef quality. This turned out to be a compromise and, depending on the breed and the main goal of production, a longer or shorter finishing period may be advantageous. The data obtained indicate, to a certain degree, the possible consequences of extending or shortening this period. It has to be stated that the age at the slaughter of only about 1 year for the PI heifers, independent of being finished or not, was early for this breed.

In all breeds, finishing successfully compensated for initial differences in BW. Accordingly, when aiming for a fixed slaughter weight, either a minimum starting BW before the alpine summer must be defined, or if cattle of various BW are used, then a finishing strategy is needed. Effects on performance and meat quality will influence the choice of the preferred strategy. One of the limitations of an extensive feeding period is that animals slaughtered directly afterwards have unfavourable carcases with a low conformation score, fat cover and IMF (Gangnat et al. 2016). The substantial compensatory growth found in the VC and VR during finishing was of great economic importance. The phenomenon of compensatory growth (e.g. Yambayamba et al. 1996) is an efficient means to strategically utilise feed of low quality across extended periods. This strategy also results specifically in high muscle formation and less fat accretion. Considering that the PI did not grow in the grass-feeding period, the level of daily gains in the finishing period was astonishingly low and still inferior to those of the VC and VR. This is also why finishing the PI, compared to the VC and VR, did not enhance the fat cover.

Starting at a very low level, finishing almost doubled IMF across all breeds. However, a major draw-back caused by finishing in the present study was the trend for impairment of beef tenderness, especially in the LT, consistent with the dependence on the muscle described by Shorthose and Harris (1990). Beef tenderness indeed decreases with age (Tatum 2011), but little impairment is expected in cattle younger than 2 years (Field et al. 1966). The present results indicate differently. It was puzzling that in the LT, connective tissue properties (lower collagen solubility) were even improved by finishing, whereas the opposite was expected from the age-dependent formation of crosslinks between collagen fibres. It is likely that the trend towards a lower tenderness was also responsible for the consumer statement that the price was more appropriate for the beef from the non-finished than finished cattle. The concomitant reduction of uncommon smell and taste, probably caused by switching from grass to a mixed diet during finishing, was obviously less important to the Italian consumers. American consumers, by contrast, have an aversion to the grassy flavour of pastured beef compared to beef from grain-fed cattle (Griebenow et al. 1997; Maughan et al. 2012).

Finishing increased ultimate pH but not to the range of dark, firm, dry meat with pH <6.2 or 6.0 (Heinz and Hautzinger 2007). Concerning meat colour, the effects of finishing were inconsistent between the LT and BF samples. Extensive production systems, where cattle practise more intensive physical activity, were linked with darker muscles (Vestergaard et al. 2000), and carotenoids from grass might add yellow colour, which is the opposite of what was found in the BF. The latter effect is, however, much more pronounced in the colour of adipose tissue (Velik et al. 2013).

Most types of finished beef (independent of breed and ageing period) were rated as too expensive by the consumers. When they did not know which type of meat they assessed, these price-related statements were related to texture. With additional information about the region of rearing and regional origin of the breed, the price tolerance increased, but the higher price tolerance merely counteracted the disadvantages of finishing. van Rijswijk et al. (2008) emphasised the great importance of traceability for consumers in four European countries and illustrated the relationship between product origin, control and security. However, the special quality of 'regional origin' could not be valorised as well in the case of finishing. Another important argument against finishing with a concentrate-based lowland diet is given by the likely quick dilution of the special fatty acid profile from grass-feeding in general and from an alpine sojourn in particular. This was demonstrated by Gangnat et al. (2016) in cattle receiving grass at high altitude and finished on concentrate and a mix of grass silage and maize silage.

Effect of ageing period of the meat

Prolonged ageing (here 28 vs. 7 days) was anticipated to be helpful in tenderising the meat because stable myofibril structures can be more intensively disintegrated by calpains (Koohmaraie et al. 2002). However, no such effects were found in shear force and consumers' tenderness impression of the LT. The consumers' more tender impression of the longer-aged BF was not substantiated by corresponding changes in shear force. Gruber et al. (2006), but not Colle et al. (2016), found that ageing effects are muscle dependent. The generally low effect of ageing on meat texture could either be due to myofibrillar tissue properties being less important than those of the connective tissue properties or that the majority of meat tenderisation had already happened within 7 days in the present study. Indeed, Campo et al. (2000) found texture effects only between 1, 3 and 7 days of ageing and not with prolonged ageing. Razminowicz et al. (2008) registered a clear decline in shear force of the LT when increasing ageing time from 2 to 15 days, but no further decline with 29 days of ageing. The BF also did not attract higher tenderness scores when aged for longer than 21 days (Colle et al. 2016). Campbell et al. (2001), however, found shear force effects of ageing only between 14 and 21 days. Colle et al. (2016) concluded that a higher tenderness obtained with ageing was more important to consumers than the potential discolouration associated with ageing. In the present study, there were no indications that prolonged ageing caused meat to be more susceptible to discolouration. Both muscles were redder after 28 days compared to 7 days of ageing, and the concomitant increase in lightness did not indicate discolouration. Prolonged ageing also had only weak effects on the occurrence of uncommon flavours in the present study. This finding differs from that of Campbell et al. (2001), who reported the prevalence of bloody and metallic tastes to be slightly decreased in beef aged for 21 days compared to non-aged beef. However, this could be short-lived, because Yancey et al. (2005) found more uncommon flavours when ageing was prolonged from 21 to 35 days. As the ageing period in the present study (28 days) fell within this range, this may explain the lack of effect on off-flavours. Based on these results, it was unexpected that prolonged ageing resulted in generally positive consumer assessments of the BF. Although Gagaoua et al. (2016) associated overall liking of different meat types also with their flavour properties, tenderness is likely more important. As a result of the favourable sensory perception of meat that has been aged longer, the consumers also perceived the given price for such meat as cheap compared to that aged only for 7 days. This indicates that, when ageing is successful, a higher meat price might help to compensate for the higher refrigeration costs. In addition, the favourable sensory perception may be beneficial for marketing beef of regional origin from regional breeds more successfully at a higher price.

Recovery of breed differences after finishing and prolonged ageing of the meat

Finishing delivered slightly positive results in terms of carcase fat covering in the heifers of the VC and VR, but not in the PI. In turn, LT shear force and toughness were least affected by finishing in the PI and most in the VC (this was also substantially so in LT aged for 28 days). This was one of the very few differences between the VC and VR, and favoured the VR, which showed the LT maturing at a later age. In contrast, Mezgebo et al. (2017) compared early- and late-maturing beef breeds finished with or without concentrate and found no interactions between breed and finishing treatment in physicochemical and sensory traits.

There were only a few breed × ageing interactions, suggesting that breed differences in tenderness were mainly caused by connective tissue properties. Monsón et al. (2005) observed an interaction between cattle breed and ageing in tenderness, but only until 7 days of ageing. No differences in the response to the ageing of the LT of four different breeds were reported for shear force by Campo et al. (2000). In the present study, it seems that ageing affected sensory perception more strongly and differently in the PI and VC than in the VR. There is no obvious explanation for this phenomenon. In contrast to what was hypothesised, the present data did not indicate that low tenderness, as presumed for the Valdostana breeds, can be compensated for by a prolonged ageing period.

Finishing × ageing interactions were rare. The meat colour traits did not change in a systematic way; therefore, the colour cannot be associated with intake of grass antioxidants or the mixed forage-concentrate finishing diet. It was not possible to counteract the adverse effects of finishing on tenderness by extending the ageing period to 28 days, probably because finishing increased connective tissue-based and not myofibril-based toughness.

Limitations of the study

A number of indicative interactions between breed type and the two measures intended to improve performance, carcase and meat quality, namely finishing of the heifers and prolonged ageing of the meat, were tested, and the interpretation of the results and drawing of conclusions must be done with care. This is particularly important when comparing the dual-purpose breed with the beef breed heifers. The beef breed heifers, endemic to the study region, had to remain indoors in the lowlands and were fed on grass only for a shorter time. Another limitation was that, due to the shortage of meat samples for both sensory assessments (the trained panel and consumers), different muscles had to be used.

Conclusions

The differences in performance and meat quality between the two Valdostana breeds, Chestnut and Red Pied, were rather small, especially in unfinished animals; thus, hypothesis (1) was mostly disproven. Still, the clearly different genetic origins and the differences in LT texture could work in favour of marketing the meat from these two breeds under different labels. Different from what had been assumed in hypothesis (2), finishing in the lowlands had no effect on carcase quality and was even disadvantageous for meat quality. Therefore, only animals with sufficiently high body weights should be employed in the transhumance system; this also avoids the loss of the additional human nutritional value of the lipids in such beef. Prolonging meat ageing from 7 to 28 days resulted in some improvements, such as weakened off-flavours (for LT) and better tenderness impression (for BF). However, the process was not as effective as expected, thus partially disproved hypothesis (3). Including heifers from two autochthonous breeds provided our study with beef of regional origin, which allowed exploration of the hypothesis (4). The hypothesis was confirmed by the results that showed consumers acknowledged the beef origins in their price worthiness assessments. Still, as anticipated, the carcase and meat quality (particularly of the LT) of the dual-purpose breed heifers that performed an alpine sojourn were not comparable to that of the grass-fed beef breed cattle (Piedmontese). This confirms hypothesis (5). This difference in quality will have to be compensated for by high-priced and high-quality meat cuts, such as the BF valorised with the claim of ‘regional origin’.

Ethical approval

The experiment was conducted in compliance with the EU Directive 2010/63/E.U. for animal welfare and was approved by the veterinary office of the Aosta region.

Acknowledgements

The authors are particularly grateful to Nadine Herrmann for providing the basis of this article through her master’s thesis. We thank the Association Régionale Eleveurs Valdôtains and the breeders of the Aosta valley for their valuable collaborations. The authors thank the Institute Agricole Régional for their facilitation of the experiment, the Zürcher Hochschule für Angewandte Wissenschaften for support during descriptive analysis, and the Fondazione per la Formazione Professionale Turistica for the possibility and assistance in conducting the consumer test.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

Ådnøy T, Haug A, Sørheim O, Thomassen MS, Varszegi Z, Eik LO. 2005. Grazing on mountain pastures – does it affect meat quality in lambs? Livest Prod Sci. 94(1–2):25–31.

AOAC. 2006. Official methods of analysis. Arlington (VA): Association of Official Analytical Chemists.

AOAC. 2009. Official methods of analysis. Arlington (VA): Association of Official Analytical Chemists.

Campbell RE, Hunt MC, Levis P, Chambers E. 2001. Dry-aging effects on palatability of beef *longissimus* muscle. J Food Science. 66(2):196–199.

Campo MM, Santolaria P, Sañudo C, Lepetit J, Olleta JL, Panea B, Albertı´ P. 2000. Assessment of breed type and ageing time effects on beef meat quality using two different texture devices. Meat Sci. 55(4):371–378.

Chambaz A, Kreuzer M, Scheeder MRL, Dufey PA. 2001. Characteristics of steers of six beef breeds fattened from eight months of age and slaughtered at a target level of intramuscular fat. Arch Anim Breed. 44(5):473–488.

Cocca G, Sturaro E, Gallo L, Ramanzin M. 2012. Is the abandonment of traditional livestock farming systems the main driver of mountain landscape change in Alpine areas? Land Use Pol. 29(4):878–886.

Colle MJ, Richard RP, Killinger KM, Bohlscheid JC, Gray AR, Loucks WI, Day RN, Cochran AS, Nasados JA, Doumit ME. 2016. Influence of extended aging on beef quality characteristics and sensory perception of steaks from the *biceps femoris* and *semimembranosus*. Meat Sci. 119:110–117.

Field RA, Nelms GE, Schoonover CO. 1966. Effects of age, marbling and sex on palatability of beef. J Anim Sci. 25(2): 360–366.

Gagaoua M, Terlouw EMC, Micol D, Hocquette J-F, Moloney AP, Nuernberg K, Bauchart D, Boudjellal A, Scollan ND, Richardson RI, et al. 2016. Sensory quality of meat from eight different types of cattle in relation with their biochemical characteristics. J Integrat Agric. 15(7):1550–1563.

Gangnat IDM, Kreuzer M, Clavijo McCormick A, Leiber F, Berard J. 2016. Carcass and meat quality of finished and non-finished Limousin heifers from alpine livestock systems differing in altitudinal origin of the forage. Arch Anim Nutr. 70(2):108–126.

Gangnat IDM, Leiber F, Dufey P-A, Silacci P, Kreuzer M, Berard J. 2017. Physical activity, forced by steep pastures, affects muscle characteristics and meat quality of suckling beef calves. J Agric Sci. 155(2):348–359.

García-Martínez A, Bernués A, Olaizola AM. 2011. Simulation of mountain cattle farming system changes under diverse agricultural policies and off-farm labour scenarios. Livest Sci. 137(1–3):73–86.

Gellrich M, Baur P, Koch B, Zimmermann NE. 2007. Agricultural land abandonment and natural forest re-growth in the Swiss mountains: a spatially explicit economic analysis. Agric Ecosyst Environm. 118(1–4):93–108.

Griebenow RL, Martz FA, Morrow RE. 1997. Forage-based beef finishing systems: a review. J Prod Agric. 10(1):84–91.

Gruber SL, Tatum JD, Scanga JA, Chapman PL, Smith GC, Belk KE. 2006. Effects of postmortem aging and USDA quality grade on Warner-Bratzler shear force values of seventeen individual beef muscles. J Anim Sci. 84(12):3387–3396.

Heinz G, Hautzinger P. 2007. Meat processing technology for small- to medium-scale producers. Bangkok (Thailand): Food and Agriculture Organisation of the United Nations, Regional Office for Asia and the Pacific.

Honikel KO. 1998. Reference methods for the assessment of physical characteristics of meat. Meat Sci. 49(4):447–457.

Khiaosa-Ard R, Soliva CR, Kreuzer M, Leiber F. 2011. Influence of alpine forage either employed as donor cow's feed or as incubation substrate on *in vitro* ruminal fatty acid biohydrogenation. Livest Sci. 140(1–3):80–87.

Koohmaraie M, Kent MP, Shackelford SD, Veiseth E, Wheeler TL. 2002. Meat tenderness and muscle growth: is there any relationship? Meat Sci. 62(3):345–352.

Liu A, Nishimura T, Takahashi K. 1996. Relationship between structural properties of intramuscular connective tissue and toughness of various chicken skeletal muscles. Meat Sci. 43(1):43–49.

Maughan C, Tansawat R, Cornforth D, Ward R, Martini S. 2012. Development of a beef flavor lexicon and its application to compare the flavor profile and consumer acceptance of rib steaks from grass- or grain-fed cattle. Meat Sci. 90(1):116–121.

Mazza S, Sartori C, Mantovani R. 2015. Genetic parameters of type traits in two strains of dual purpose autochthonous Valdostana cattle. Livest Sci. 178:35–42.

Mezgebo GB, Monahan FJ, McGee M, O'Riordan EG, Picard B, Richardson RI, Moloney AP. 2017. Biochemical and organoleptic characteristics of muscle from early and late maturing bulls in different production systems. Animal. 11(9):1636–1644.

Monsón F, Sañudo C, Sierra I. 2004. Influence of cattle breed and ageing time on textural meat quality. Meat Sci. 68(4):595–602.

Monsón F, Sañudo C, Sierra I. 2005. Influence of breed and ageing time on the sensory meat quality and consumer acceptability in intensively reared beef. Meat Sci. 71(3):471–479.

Preiswerk Y, Crettaz B. 1986. Le Pays ou les vaches sont reines. Monographics S.A. Sierre. Collection Mémoire vivante

Razminowicz RH, Kreuzer M, Scheeder MRL. 2008. Effect of electrical stimulation, delayed chilling and postmortem ageing on the quality of *M. longissimus dorsi* and *M. biceps femoris* of grass-fed steers. J Sci Food Agric. 88(8):1344–1353.

Ritchie H. 2009. Breeds of beef and multi-purpose cattle. East Lansing (MI): Michigan State University; [Accessed 2020 July]. https://www.canr.msu.edu/uploads/236/58553/breedsofbeefcattle_ritchie.pdf

Sartori C, Mantovani R. 2010. Genetics of fighting ability in cattle using data from the traditional battle contest of the Valdostana breed. J Anim Sci. 88(10):3206–3213.

Shorthose WR, Harris PV. 1990. Effect of animal age on the tenderness of selected beef muscles. J Food Science. 55(1):1–8.

Tatum JD. 2011. Animal age, physiological maturity, and associated effects on beef tenderness. Calgary (Canada): Beef Research; [Accessed July 2020]. https://www.beefresearch.org/CMDocs/BeefResearch/PE_White_Papers/Animal_Age.pdf

van Rijswijk W, Frewer LJ, Menozzi D, Faioli G. 2008. Consumer perceptions of traceability: a cross-national comparison of the associated benefits. Food Qual Pref. 19(5):452–464.

Velik M, Gangnat I, Kitzer R, Finotti E, Steinwidder A. 2013. Fattening heifers on continuous pasture in mountainous regions–implications for productivity and meat quality. Czech J Anim Sci. 58(8):360–368.

Vestergaard M, Oksbjerg N, Henckel P. 2000. Influence of feeding intensity, grazing and finishing feeding on muscle fibre characteristics and meat colour of *semitendinosus*, *longissimus dorsi* and *supraspinatus* muscles of young bulls. Meat Sci. 54(2):177–185.

Yambayamba ESK, Price MA, Jones SDM. 1996. Compensatory growth of carcass tissues and visceral organs in beef heifers. Livest Sci. 46(1):19–32.

Yancey EJ, Dikeman ME, Hachmeister KA, Chambers E, Milliken GA. 2005. Flavor characterization of top-blade, top-sirloin, and tenderloin steaks as affected by pH, maturity, and marbling. J Anim Sci. 83(11):2618–2623.