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Transhumance of dairy cows to highland summer pastures interacts with breed to influence body condition, milk yield and quality

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ABSTRACT

This paper aimed at testing the differences of adaptability of bovine dairy, dual purpose and local breeds during the summer transhumance to highland pastures (summer farms), evaluating temporal variations of body condition and of milk yield and quality. Data were from 799 dairy cows of specialised (Holstein Friesian and Brown Swiss), dual purpose (Simmental) and local (mostly Rendena and Alpine Grey) breeds, and were collected before and after the transhumance in 109 permanent dairy farms, and during transhumance in 15 summer farms of the Autonomous Province of Trento, north-eastern Italy. Body Condition Score (BCS), milk production and quality (fat, protein, casein, lactose, urea, SCS) were analysed for the fixed effects of breed, parity, days in milk, month, supplementary concentrate level, and for the random effects of summer farm and individual cow. Body condition score was influenced by transhumance to summer farms, with low values in July and a recovery at the end of the period. This pattern was particularly marked in the specialised breeds. Similarly, also milk production declined, especially for Holstein Friesian and Brown Swiss, so that towards the end of transhumance all breeds had similar milk productions. Returning to permanent farms did not compensate the specialised breeds for the production loss experienced at the beginning of the grazing season. In conclusion, local and dual purpose breeds adapt better than specialised breeds to the summer pastures, and this results into an important reduction of their productive gaps (with lower variations of milk quality) and in maintaining body fat reserves.

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Introduction

Summer transhumance to highland pastures on temporary farms (hereafter called “summer farms”) has been practised since pre-historic times and is still widespread in the mountain livestock farming systems of the European Alps and of several other mountainous regions (Mack et al. 2013). This practise is important for farmers because it supplements the annual forage budget, allows access to public subsidies (Mack et al. 2013; Zendri et al. 2013; Battaglini et al. 2014), and can increase revenue through processing of the milk into high-value traditional cheeses (Sturaro et al. 2013a). In addition, the cultural landscape of the summer farms provides positive externalities by increasing local tourist attractiveness (Thiene & Scarpa 2008; Daugstad & Kirchengast 2013), maintaining cultural heritage and traditions (Baudry & Thenail 2004; Kianicka et al. 2010; Eriksson 2011), supporting the

biodiversity of farmed livestock (Sturaro et al. 2013a) and conserving natural habitats and species of high conservation value (Marini et al. 2011).

The practise of transhumance to summer farms has declined over the recent decades (Mack et al. 2013; Sturaro et al. 2013b), following the general process of agricultural intensification in productive areas and abandonment of farming in marginal areas (García-Martínez et al. 2009; Bernués et al. 2011; Strijker 2005). Sustaining traditional, extensive livestock systems and high nature value grasslands is now a priority in agricultural and biodiversity policies (European Commission 2011a, 2011b), and for this purpose maintaining their links with the summer farms is essential.

Studies on the sustainability of summer farms have addressed the effects of abandonment or intensity of grazing on the biodiversity of grasslands (Parolo et al. 2011), the potential mitigating effect of summer

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grazing on the environmental impact of farming (Penati et al. 2011; Guerci et al. 2014), the effects of moving to summer pastures on animal health and welfare (Mattiello et al. 2005; Corazzin et al. 2010; Comin et al. 2011), and the influence of pasture on the sensorial and nutraceutical properties of milk (Martin et al. 2005; Gorlier et al. 2012). The effects of transhumance to summer farms on the nutritional status of animals and their milk production and quality are important issues, given that the milk is often processed into high-value products, yet so far they have been addressed in few experiments (Bovolenta et al. 1998, 2009; Leiber et al. 2006; Romanzin et al. 2013; Farruggia et al. 2014). When moved to summer pastures, cows experience a change in diet, an increased energy expenditure due to the movement associated with grazing, new interactions with unknown individuals in the case of mixed herds, and a general need to adapt to a different environment. These conditions could result in nutritional imbalance, which in turn will affect milk production and composition, and ultimately cheese yield. Normally, supplement concentrates are provided (Leiber et al. 2006; Bovolenta et al. 2009), but compensating for the nutritional deficiencies of pasture is a difficult task where animals graze in heterogeneous swards and are free to move over wide areas. This is of particular concern when comparing highly-specialised breeds with dual-purpose or local breeds, characterised by lower productive potentials and requirements, but by better adaptation to the difficult conditions of mountain pastures. Dairy systems are highly diversified in mountainous regions, where a variety of different breeds are reared, often in multi-breed farms (Mattiello et al. 2011; Sturaro et al. 2013b).

This study aimed to investigate, in a large sample of summer farms, the response to transhumance of lactating cows of dairy, dual purpose and local breeds, including the effect of the amount of supplement concentrates provided, by controlling variations of body condition score, milk yield and quality before, during and after summer pasture.

Materials and methods

Alpine highland pastures and cows sampled

Study area. This study was focussed on summer farms of the Trento Province, north eastern Italian Alps. Dairy cattle represent the Province's largest livestock sector: of the 1403 cattle farms counted in the 2010 census, 1071 raised dairy herds. The majority of dairy farms are members of cooperatives producing local and

Protected Designation of Origin (PDO) cheeses, mainly "Trentingrana", and are subject to strict regulations (Bittante et al. 2011).

Pastures for dairy cows cover a larger surface area than meadows (50,000 vs. 30,000 ha, on a total agricultural surface of 1372 km²), and are very important for the entire livestock sector in mountain areas. A summer farm (*malga* in Italian) is a temporary farm unit where a livestock herd is moved to during summer to graze on highland pastures. In the Trento Province, summer farms are mainly owned by public institutions (district councils), and each unit keeps livestock from several permanent farms. Almost all the permanent dairy farms move their heifers to summer farms, and around half move also lactating cows (Sturaro et al. 2013a).

Summer farm sampling. The data used in this study were collected from 15 summer farms, all with multi-breeds herds, and from the 109 permanent farms that moved part or all of their lactating cows to these summer farms during 2012. The summer farms were chosen on the basis of the altitude (1200 to 2000 m asl) and the amount of supplement concentrates given to the cows (low: ≤ 4 kg/d; high >4 kg/d). Supplement concentrates were mainly compound feeds and the average chemical composition was: crude protein $15.20 \pm 3.46\%$, crude fibre $8.95 \pm 4.14\%$, crude fat $3.49 \pm 0.79\%$. The two groups of farms were homogeneous for other characteristics: grazing management (continuous grazing), elevation, surface area, herd size and stocking rate (Table 1).

Collection of data from the cows

Body condition score (BCS). Two trained operators collected BCSs from 799 lactating cows in July, after adaptation following arrival (from early to mid-June) on the summer farms, and in September. Scoring was according to 5 classes (from 1, emaciated, to 5, obese), as described by Edmonson et al. (1989) for dairy breeds and adapted to dual-purpose breeds. The cows were evaluated at the moment of milking, by using a scale with 0.25 units of increments.

Milk recording. All the cows were registered in the Italian Herd Books of their breed, and in the milk recording system (AT4) of the Trento Province. Monthly milk recordings (excluding August) were collected from the Breeders Federation of Trento and comprised the last sampling in the permanent farms (in May) before transhumance to the summer farms, samplings on the summer farms (June, July and September), and the first sampling after the cows returned to the permanent farms (October). Data on daily milk yield, milk composition (fat, protein, casein,

Table 1. Number and characteristics of temporary summer farms.

Variable	Daily compound feed during summer pasture:	
	Low level (≤ 4 kg/d)	High level (>4 kg/d)
Permanent dairy farms of origin of cows (n)	77	32
Temporary summer farms – highland pasture (n)	10	5
Elevation of temporary dairy farms (m asl)	1723 \pm 194	1645 \pm 247
Pasture surface (ha/temporary summer farms)	76.0 \pm 67.9	86.9 \pm 72.7
Dairy cows per temporary summer farms (n)	62.3 \pm 31.1	76.8 \pm 49.6
Stocking rate (LU/ha)	1.05 \pm 0.59	1.14 \pm 0.54
Average supplement concentrate (kg/head/day)	3.4 \pm 0.6	5.6 \pm 1.2

LU: Livestock Units follow EU livestock schemes where cattle >2 years = 1 livestock unit, cattle 6 months to 2 years = 0.6 LU and cattle <6 months = 0.4 LU.

lactose, urea), and somatic cell count (SCC) were retrieved. Fat/protein and casein/protein ratios were calculated, and somatic cell scores (SCS) were obtained through logarithmic transformation of SCC.

Other information. All the information on individual cows (breed, date of birth and calving, number of lactations, days in milk) was retrieved from the national cattle population register. The study investigated two specialised dairy breeds: Holstein Friesian (90 cows) and Brown Swiss (314 cows); three dual-purpose breeds: Simmental (241 cows), Rendena (26 cows), and Alpine Grey (97 cows); and crossbreds (31 cows, mostly between specialised dairy and dual-purpose breeds). Given the low number of cows belonging to the last three genotypes, and their similar body sizes and productivity, they were grouped together as “Local Breeds” (154 cows) for statistical analyses. Cows of other breeds and cows not registered in the Herd Books were excluded from the analyses.

Statistical analysis

All the data referring to the cows' BCS and milk yield and composition were analysed using the MIXED procedure (SAS Institute Inc., Cary, NC). The fixed effects tested were the class of supplement concentrate (class 1: <4 kg/cow/d; class 2: >4 kg/cow/d); the breed (class 1: Holstein Friesian, class 2: Brown Swiss, class 3: Simmental, class 4: Local Breeds); the class of parity of the cow (class 1: primiparous, class 2: pluriparous); the class of DIM at the time the cow was transported to the summer farm (class 1: <120 d, class 2: 121–180 d, class 3: 181–240 d; class 4: >241 d); the class of month (for BCS: class 1: July; class 2: September; for all the other traits: class 1: May; class 2: June; class 3: July; class 4: September; class 5: October). Summer farm (15 units, nested within class of supplement concentrate) and cow (799 dairy cows, nested within class of supplement concentrate, summer farm, breed, parity, and initial DIM) were considered as random effects. After a preliminary analysis of the effects of the different interactions, the following interactions were also

included in the statistical model: class of supplement concentrate \times breed, breed \times month, initial DIM \times month. Summer farm was the error line for testing class of supplement concentrate, cow was the error line for testing breed, parity, initial DIM, and class of supplement concentrate \times breed, and the residual was the error line for testing month, breed \times month, and initial DIM \times month. Orthogonal contrasts were used to compare the classes of fixed effects as follow: Month: (1) May vs. June, (2) June vs. September, (3) July vs. June + September, (4) September vs. October; Breed: (1) Holstein Friesian + Brown Swiss vs. Simmental + Local Breeds, (2) Brown Swiss vs. Holstein Friesian, (3) Local Breeds vs. Simmental. For DIM, the linear, quadratic and cubic trends of the LSM classes were tested.

Results

Sources of variation of traits studied

The results of the mixed linear models for the traits studied are reported in Table 2. The sources of variation related to individual cow characteristics included in the mixed linear model (breed, parity, and initial DIM) significantly affected almost all the traits analysed, as did monthly variation within cow. The interactions of breed and initial DIM with month were also almost always significant. The class of supplement concentrate administered on the summer farms significantly affected only few milk quality traits (caseins and lactose %), which could be related to the high degree of variability among summer farms within compound feed level (used as the error term for testing the effect of compound feed level). The interaction class of supplement concentrate \times breed was significant only for milk urea content.

The effect of month, breed and their interaction

The effect of month is presented in Table 3. This effect combines those of moving to summer farms, of

Table 2. Analysis of variance of BCS and milk yield and quality with *F*-value and significance of fixed effects and square root of variance of random effects (each random effect is placed soon after the fixed effects for which it was used as error line).

	Feed ^a	Temporary farm (random)	Breed	Feed × Breed	Parity	Initial DIM	Cow (random)	Month	Breed × Month	Initial DIM × Month	Residual (random)
BCS (score)	2.9	±0.080	43.0***	1.3	7.0**	30.0***	±0.248	21.4***	3.7**	1.8	±0.164
Daily production:											
Milk, kg/d	2.4	±3.074	2.7*	0.8	13.8***	20.8***	±3.031	461.9***	8.2***	8.6***	±4.124
Fat + protein, kg/d	2.5	±0.228	5.9***	1.0	6.4*	5.1**	±0.220	353.9***	6.2***	4.3***	±0.292
Milk quality:											
Fat, %	0.4	±0.226	4.6**	1.5	0.5	17.8***	±0.334	20.9***	3.4***	2.0*	±0.616
Protein, %	4.1	±0.077	20.5***	1.2	4.8*	72.5***	±0.228	142.1***	7.6***	9.9***	±0.238
Fat/protein, ratio	2.7	±0.064	2.1	1.5	0.1	5.3***	±0.072	8.7***	5.0***	1.0	±0.174
Casein, %	5.4*	±0.064	20.8***	0.8	11.6***	65.9***	±0.178	96.7***	7.4***	8.8***	±0.181
Casein/protein, %	3.2	±0.297	0.2	2.4	67.7***	11.4***	±0.586	308.9***	3.4***	5.4***	±0.990
Urea, mg/100mL	0.1	±3.406	15.0***	4.3**	0.7	5.1**	±3.064	25.2***	4.8***	1.7	±6.679
Lactose, %	9.6**	±0.042	3.1*	1.7	80.1***	4.1**	±0.137	198.7***	6.6***	4.1***	±0.149
SCS	0.0	±0.611	2.2*	1.1	30.1***	4.2**	±1.233	60.2***	2.4**	2.6***	±1.231

p* < 0.05.*p* < 0.01.****p* < 0.001.^aEffect of class of temporary summer farms according to the average daily amount of compound feed given to lactating cows (<=4.0 vs. >4.0 kg).**Table 3.** Effect of the month of recording on BCS and milk yield and quality.

	Month LSM					Contrast <i>p</i> -value			
	May Permanent farm	June Summer farm	July Summer farm	September Summer Farm	October Permanent farm	May vs June	June vs September	July vs (June + September)	September vs October
BCS (score)	–	–	2.77	2.82	–	–	21.4*** ^a	–	–
Daily production:									
Milk, kg/d	22.6	20.4	15.9	11.4	14.4	65.8***	903.6***	0.0	75.8***
Fat + protein, kg/d	1.59	1.43	1.15	0.87	1.11	66.5***	688.2***	0.0	94.1***
Milk quality:									
Fat, %	3.70	3.61	3.79	3.96	3.95	4.6*	56.6***	0.0	0.0
Protein, %	3.45	3.45	3.39	3.66	3.79	0.1	142.0***	116.0***	36.3***
Fat/protein, ratio	1.08	1.06	1.12	1.07	1.06	2.8	1.5	28.8***	0.7
Casein, %	2.72	2.72	2.66	2.80	2.93	0.0	36.4***	86.8***	69.9***
Casein/protein, %	78.8	79.0	78.4	76.7	77.6	3.7	945.4***	74.0***	120.6***
Urea, mg/100mL	21.1	22.0	21.3	24.3	25.3	4.9*	19.9***	18.9***	3.5
Lactose, %	4.88	4.81	4.68	4.60	4.71	45.4***	355.6***	5.3*	69.8***
SCS	2.73	2.89	3.58	3.90	3.55	3.4	122.4***	5.8*	11.4***

p* < 0.05.**p* < 0.001.^aJuly vs September.

advancing lactation stage within each cow, of changes in pasture and environmental conditions, and of returning to permanent farms.

The contrast between data collected in May and data collected in June represents, together with an one-month advancement in lactation, the main effect of moving cows from permanent lowland farms to summer farms. This resulted in largely negative effects for both production traits, but influenced only marginally quality traits.

The contrast between data obtained in June and data obtained in September, i.e. the initial and final phases of summer transhumance, mainly reflects, together with three months advancement in lactation, adaptation of the cows to the new environment, plus the variation in environmental conditions and

especially in pasture quality and availability. There were large differences between the initial and final stages of the summering season for all trait categories. The trends in this variation were as could be generally expected with the advancement of lactation stage, but their amount was larger than what could be expected. This is especially true for the decreases in daily milk (–42%) and fat + protein (–36%) yields, the increase in milk fat (+8%), protein (+7%), and SCS (+34%) contents, and the decreases in the casein index (–3.5%) and in lactose content (–5.5%).

The contrast between the data collected in July and the average of those obtained in June and September reflects possible non-linear trends in observed traits from the beginning to the end of the summer transhumance. A non-linear trend was indeed observed,

especially for milk quality traits, while a linear change over time was more common for production traits and fat content. The traits most deviating from linearity were protein and casein contents, which slightly decreased from June to July and increased from July to September.

The last contrast (September vs. October) reflects, together with a further advancement of lactation, the effect of the cows returning to the permanent farms in the valleys, an indoor environment, and a more controlled feeding regime based on preserved feed-stuffs. This caused a general improvement in both milk yield and quality.

The effect of breed on BCS, milk yield and quality is presented in Table 4. Breed, within summer farm and corrected for the effects of class of parity, initial DIM and month of scoring, considerably influenced BCS. The LSM for BCS was very low for Holstein Friesian, intermediate for Brown Swiss and higher for dual-purpose breed groups, especially Local Breeds. Figure 1 shows the interaction between breed and month. Values of July reflect body condition after the first, most stressing period of summering, while those of September reflect body condition at the end of summering. The Holstein Friesian cows showed the largest difference between the July and September values, while for the other breeds, and especially Brown Swiss, these differences were less marked.

Daily productions of milk and fat-protein were not highly influenced by breed because the slight superiority of specialised over dual-purpose breeds was due to the 10% lower yield of milk and solids in local breeds.

The comparisons of milk quality traits clearly show that there were greater differences between the two specialised dairy breeds (Holstein Friesian and Brown Swiss) and between the two dual-purpose breed groups (Simmental and local breeds), although to a lesser extent, than there were between the group of specialised breeds and the group of dual-purpose breeds.

In fact, the milk from Brown Swiss cows was more concentrated (more fat, protein, casein and lactose) than that from Holstein Friesians, and milk urea was higher. Within dual-purpose breeds, Simmental cows produced milk with more fat (as % and as ratio with protein) and with a lower SCS than the local breeds.

The LSmeans of milk yield and quality due to the interaction between breeds and months are presented in Figure 2. It clearly shows how the breeds were ranked according to their expected daily milk yield in May (Holstein Friesian > Brown Swiss > Simmental > Local Breeds) and that this was almost unchanged in

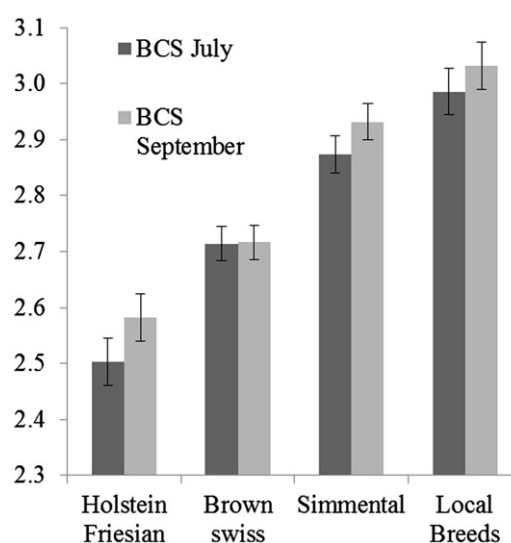


Figure 1. BCS of cows of different breed after the adaptation and at before the end of summer transhumance (interaction breed \times month, $p < 0.05$).

June, at the beginning of summer grazing, whereas one month later production of the cows of the two specialised dairy breeds dropped rapidly to the level of the local breeds. In the following two months, production of the Simmental cows also decreased a little, so that in September all breeds were very similar in terms of the quantity of milk produced. It is also worth noting that the positive effect of returning to permanent farms was very similar across breeds and did not privilege the more specialised ones, there being no compensation for the large production loss they experienced at the beginning of the grazing season. As a consequence, over the whole period daily production of fat and protein was very similar across breeds, with the exception of cows of the local breeds, whose production was slightly lower ($\sim 10\%$) (Table 4).

Variability among summer farms and the effect of class of supplement concentrate

The effects of class of supplement concentrate and of variance among summer farms on total variance are presented in Table 5.

The differences in the LSMs of BCS between the group of summer farms supplementing lactating cows with high amounts of supplement concentrate and those supplementing with low amounts were modest; also the variability in BCS among different summer farms within class of supplement concentrate was very low, representing only about one fifteenth of total variance (the sum of farm, animal and residual variances).

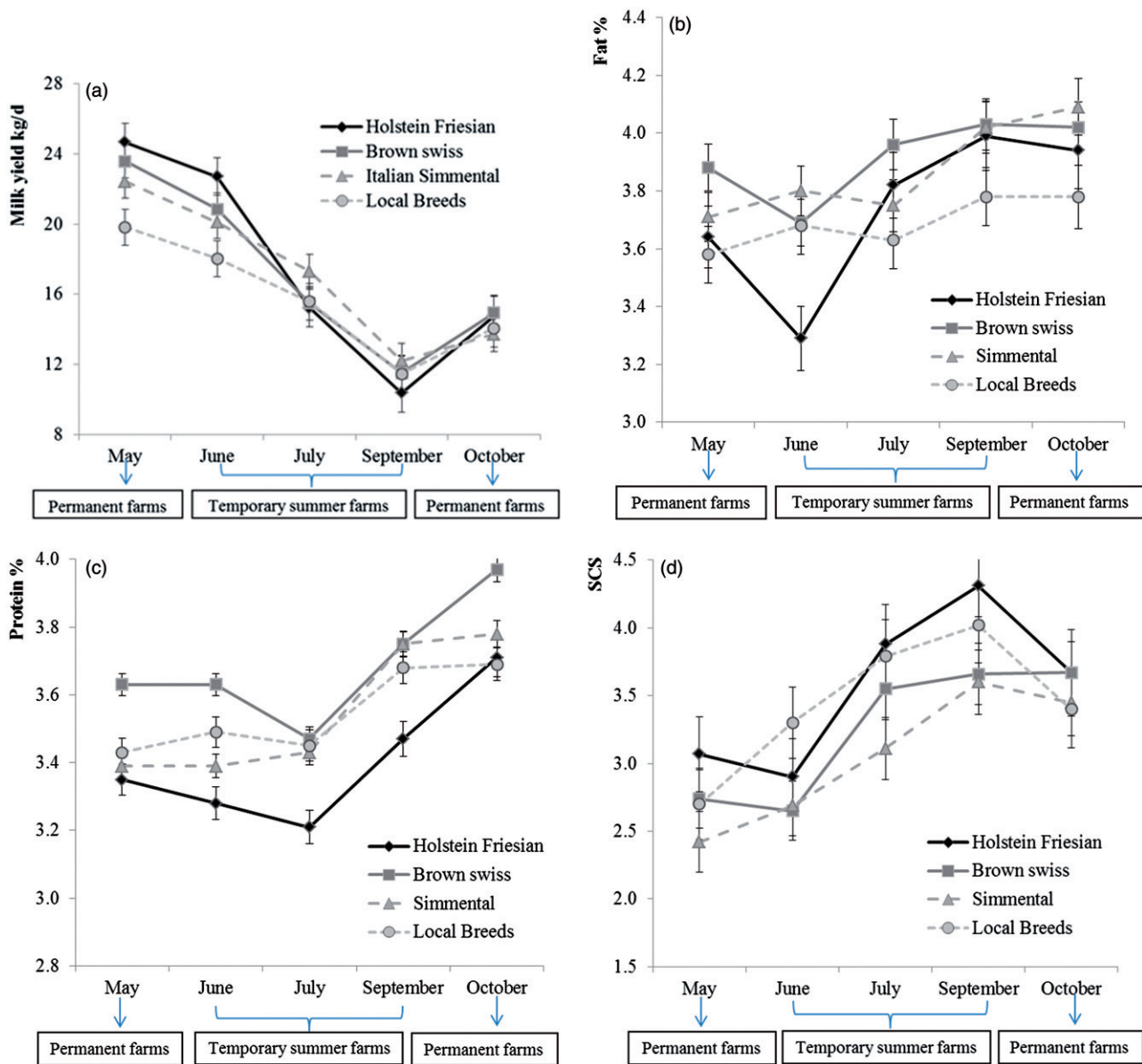


Figure 2. Milk yield (a), milk fat (b) and protein (c) content, and somatic cell score (d) of cows of different breeds before, during, and after summer transhumance.

The difference in daily production of the cows between the two groups of summer farms was high but not significant (+17% at the “high” level of supplementation for both milk yield and milk fat + protein yield). A reason for this could be that it was tested on a very large variance (almost one third of total variance) among individual summer farms within each group for both traits.

Variability among summer farms within groups was very low for milk quality traits, being less than one tenth for all traits with the exception of milk urea content (one sixth) and SCS (one eighth). Cows on the “high level” summer farms produced milk with more casein, expressed both as milk weight (casein percentage) and as total protein (casein index). The lactose

content of milk was also greater on “high level” summer farms (Table 5).

Variability among animals and the effect of parity

The effect of animal variance on total variance, and the LSMs of the effect of parity, are shown in Table 5, together with the figures for summer farms and compound feed supplementation.

Primiparous cows had higher BCSs, despite the fact that animal variance (with respect to parity) represented about two thirds of total variance. As expected, the opposite effect (lower values with primiparous than with multiparous cows) was found with the two daily production traits. Animal variance on these traits

Table 4. Effect of breed of cows on BCS and milk yield and quality.

	Breed LSM				Contrast <i>p</i> -value		
	Holstein Friesian (HF)	Brown Swiss (BS)	Simmental (SI)	Local breeds (LB)	(HF + BS) vs (SI + LB)	BS vs HF	LB vs SI
BCS (score)	2.54	2.72	2.90	3.01	128.2***	20.8***	6.6**
Daily production:							
Milk, kg/d	17.6	17.3	17.2	16.0	4.8*	0.2	5.1*
Fat + protein, kg/d	1.23	1.30	1.26	1.13	5.6*	2.9	8.6**
Milk quality:							
Fat, %	3.73	3.91	3.85	3.69	0.6	6.4*	5.9*
Protein, %	3.41	3.69	3.55	3.55	0.0	55.1***	0.0
Fat/protein, ratio	1.09	1.08	1.09	1.05	1.4	1.1	5.3*
Casein, %	2.65	2.88	2.77	2.77	0.1	56.8***	0.0
Casein/protein, %	78.1	78.0	78.1	78.1	0.1	0.4	0.1
Urea, mg/100mL	21.0	25.2	23.0	21.9	1.5	34.8***	2.2
Lactose, %	4.69	4.74	4.73	4.77	4.6*	5.5*	2.7
SCS	3.57	3.25	3.05	3.44	1.1	2.3	3.1*

**p* < 0.05.

***p* < 0.01.

****p* < 0.001.

Table 5. Effect of class of temporary summer farms according to the amount of compound feed given to cows (feed) and of parity of cows and percentage incidence of variance of temporary farm, within class of feed, and of cow on total variance of BCS and milk yield and quality.

	Feed LSM		Temporary farm, %	Parity LSM		Cow ^a %
	Low level	High level		Primiparous	Pluriparous	
BCS (score)	2.75	2.84	6.7	2.82 ^B	2.76 ^A	65.0
Daily production:						
Milk, kg/d	15.6	18.3	26.5	16.3 ^A	17.6 ^B	25.8
Fat + protein, kg/d	1.13	1.33	28.1	1.20 ^A	1.26 ^B	26.0
Milk quality:						
Fat, %	3.84	3.76	9.4	3.82	3.79	20.6
Protein, %	3.50	3.60	5.2	3.57 ^a	3.52 ^b	45.3
Fat/protein, ratio	1.11	1.05	10.2	1.08	1.08	13.2
Casein, %	2.72 ^a	2.81 ^b	5.6	2.80 ^B	2.74 ^A	46.5
Casein/protein, %	77.9 ^A	78.2 ^B	6.2	78.3 ^A	77.8 ^B	24.3
Urea, mg/100mL	22.6	23.0	17.7	22.9	22.6	14.3
Lactose, %	4.69 ^A	4.78 ^B	4.2	4.80 ^B	4.67 ^A	43.9
SCS	3.30	3.36	10.9	2.99 ^A	3.66 ^B	44.6

^{a,b}*p* < 0.05.

^{A,B}*p* < 0.01.

^aPercentage of variability explained by the random effect of cow.

represented slightly more than a quarter of total variance.

The individual cow was an important source of variability in all milk quality traits, ranging from about one seventh for the fat/protein ratio and urea content, almost a quarter for milk fat and one third for the casein index, to almost one half for the other traits (protein, casein, lactose and SCS). Lower milk production in primiparous cows was paralleled by a favourable effect on some quality traits (protein, casein, casein index, lactose and SCS).

Effect of stage of lactation at the beginning of summer pasture

The effect of initial days in milk is presented in Table 6. This factor does not represent the effect of advancing lactation within each cow, but shows the differences between cows at different stages of

lactation when they were moved to summer farms for transhumance to Alpine pastures.

A strong linear trend was observed for all traits, with smaller quadratic and cubic effects for some of the traits exhibiting a greater difference between the first (<120 DIM) and the second (121–180 DIM) class of DIM at the beginning of summer pasturing than between the third (181–240 DIM) and the fourth (>240 DIM) classes. As expected, the effect of initial DIM was positive for BCS, negative for production traits, positive for milk quality traits, except lactose, urea and the two ratios examined.

Discussion

Milk production

Summer transhumance of cows from lowland permanent farms to summer farms involves a change from

Table 6. Effect of DIM at the transport of cows to temporary summer farms on BCS and milk yield and quality.

	Initial days in milk LSM				Contrast <i>p</i> -value		
	<120	121–180	181–240	>241	Linear	Quadratic	Cubic
BCS (score)	2.64	2.77	2.82	2.94	83.6***	0.0	3.1
Daily production:							
Milk, kg/d	19.2	16.9	15.9	15.8	56.1***	10.7**	0.1
Fat + protein, kg/d	1.31	1.22	1.19	1.20	12.0***	4.6*	0.2
Milk quality:							
Fat, %	3.59	3.73	3.95	3.94	47.2***	3.7	3.5
Protein, %	3.28	3.52	3.64	3.75	215.4***	7.5**	1.2
Fat/protein, ratio	1.10	1.07	1.09	1.05	7.3**	0.8	6.6**
Casein, %	2.57	2.74	2.84	2.92	196.0***	8.3**	0.4
Casein/protein, %	78.3	78.1	78.1	77.8	29.2***	0.6	2.8
Urea, mg/100mL	23.3	23.8	21.8	22.2	8.1**	0.0	7.4**
Lactose, %	4.77	4.74	4.74	4.70	10.6***	0.1	1.0
SCS	2.95	3.37	3.45	3.54	11.2***	2.0	0.5

p* < 0.05.*p* < 0.01.****p* < 0.001.

mostly indoor rearing, with a constant ration of hay and concentrates or a total mixed ration (Sturaro et al. 2013a), to outdoor rearing and feeding on pasture. Many of the old barns on traditional summer farms have been transformed into milking parlours, so the cows live outdoors day and night, and only return to the barn for milking (Zendri et al. 2013).

Alpine pastures are characterised by low productivity, a short vegetative season, and a marked variation in grass availability, botanical proportion and chemical composition (Bovolenta et al. 1998). The cows are required to walk long distances, often on steep, stony inclines covered with shrubs, which may limit their grass intake and make them also susceptible to the negative effects of anoxia (Leiber et al. 2006). The cows are normally given a concentrate feed supplement during milking, but the amount and composition are rather variable, as observed also in our study. The compound feed is sometimes modified during summer grazing to increase the crude protein content (Leiber et al. 2006).

From the environmental and nutritional points of view, summer transhumance causes stress during the first period of grazing (Zemp et al. 1989), also for the mixing of cows from different permanent farms. The stressful conditions are confirmed by a progressive decrease in milk production, leading to the daily yield being almost halved in four months (Table 3), and by the recovery of production functions after the cows return to the permanent farms. Farruggia et al. (2014), found a decrease in milk production from May to September of about 35% for cows grazing a rotational productive pasture, and 60% for cows on a continuous permanent pasture characterised by low productivity.

An important outcome of the present study was evidence regarding the different effects of summer

transhumance on the milk yield of cows of different breeds (interaction between breed and month). As described in the 'Results' section, during summer transhumance the specialised breeds suffered a stronger production loss than Simmental and Local Breeds. In a trial investigating the effect of concentrate supplementation on a low-input mountain experimental farm practising pasture without summer transhumance, Horn et al. (2014a) compared a specialised dairy breed (Austrian Brown Swiss) with a Friesian strain selected for life-time milk yield and fitness traits in a low-input farming systems. These authors observed that over the whole experimental period the specialised dairy breed was not able to express its productive potential in this dairy system, so that the average milk yield was similar for the two breeds even though it was higher in the specialised dairy breed at the beginning of lactation. In another paper of the same group (Horn et al. 2014b), the authors observed an effect of interaction between breed and initial DIM on milk yield and body weight change.

To limit the negative effects of summer transhumance on milk yield and body condition, the amount of supplementary concentrate is usually increased during the summer, especially with specialised dairy breeds (Bovolenta et al. 1998). In the present study, an increase in the concentrate supplement had no significant effects on the production traits, which is due to the fact that the observation unit is the summer farm so the number of independent observations (and degrees of freedom) was limited. However, the increase in milk yield (+17%) was not much different numerically from that obtained in trials comparing cows of the same summer farm fed on different amounts of concentrates (Bovolenta et al. 1998). In their investigation into the effect of concentrate

supplementation on a low-input mountain experimental farm practising pasture without summer transhumance, Horn et al. (2014a) found an increase in total lactation milk yield of about 10% for cows receiving a higher concentrate supplementation.

Body condition

The decrease in milk production on the whole averted a dramatic depletion of body fat depots. It is well known that body fat depots are important in maintaining milk yield at the beginning of lactation, but less so during mid- and late-lactation (Roche et al. 2009). In fact, the LSM of BCS was very low in July (Table 3) and increased a little during the following two months, but without reaching the values typical of the last stage of lactation (Gallo et al. 1996). The differences among the breeds with respect to this trait were even larger than with respect to daily milk yield, and the ranking of breeds was, as expected, reversed (Table 4). The breed \times month interaction was also significant in this case, but much less so than for milk yield. Figure 2 shows that at the end of the summer transhumance Holstein Friesian cows, despite a great drop in production and despite being the cows with the greatest increase in BCS from July to September, were still characterised by a very low level of body reserves, which probably prevented recovery to the desired level before the following parturition.

The amount of supplementary compound feed is usually increased during the summer also to limit the negative effects of summer transhumance on body condition, but, in the present study, the increase in the concentrate supplement had no significant effects on BCS, confirming the small effect on BCS of different levels of concentrates supplementation found by Horn et al. (2014a).

Milk quality

The effects of changes in environment, nutrition and cow management due to summer transhumance are reflected in modifications to quality traits of the milk produced before, during and after transhumance (Table 3). After moving to summer farms on Alpine grassland, milk fat content decreased while protein content remained constant. This could be due to an impairment of rumen fermentation brought about by a decrease in dry matter intake, along with a decrease in fibre content resulting from the presence of grass at a very early vegetative stage, but it could also be due to an increased intake of PUFA that promotes the rumen production of vaccenic acid and conjugated

linoleic acid (CLA) isomers. In particular, the increased availability of C18:2 ω 10c12 isomer seems to be the main factor responsible for milk fat depression (Bauman et al. 2008; Shingfield et al. 2010; Schiavon et al. 2015), which is indirectly confirmed by the study of Leiber et al. (2006) in Brown Swiss cows that showed a milk fat depression when moving to Alpine pastures from closed barns rather than from lowland pastures, i.e. from diets associated to a low rather than a high availability of such isomers. This drop in the milk fat content at the beginning of summer pasturing was particularly evident in cows of the specialised dairy breeds (Holstein Friesian and Brown Swiss) but not in dual-purpose cows (Figure 2).

During the following months, the milk fat content increased, as expected with the advancement of lactation, while milk protein and casein contents decreased in July and increased thereafter (in fact, the fat/protein ratio peaked in July). This pattern could be due to a prolonged shortage of energy that only led to a decrease in milk yield and an increase in milk protein and casein contents in the mid-term (Table 3). This pattern of milk protein content after cows were moved from lowland to Alpine pastures was also observed by Leiber et al. (2006). This interpretation is consistent with the effect of a high level of concentrate supplementation, which contributed to increasing the casein content, as well as the casein/protein ratio, and the lactose content of milk (Table 5). Bovolenta et al. (1998) found similar results for milk protein content. Further confirmation comes from the observation that the decrease in the milk protein percentage in July occurs in cows in early- and mid-lactation, but not in those in late-lactation (data not shown), and in cows belonging to specialised dairy breeds (Holstein Friesian and Brown Swiss) but not dual-purpose breeds (Figure 2).

Variations in milk lactose and SCS during summer transhumance are greater than expected as a result of lactation advancement, and could be an indicator of the increased incidence of subclinic mastitis in highland pastures (Leiber et al. 2006). Different patterns in SCS before, during and after summer transhumance were noted for cows of specialised dairy and dual-purpose breeds (Figure 2).

Conclusions

Differently to previous research, the present study was carried out not only during the period spent by cows on temporary summer farms on Alpine grassland, but also during the previous and subsequent periods spent in permanent lowland farms, allowing analysis

to be made of the changes due to moving to and returning from summer farms. Moreover, the study was carried out on several summer farms under different management schemes and, in particular, administering different quantities of compound feed to the cows, while each temporary farm reared cows of different breeds in the same environment. Finally, it combined monitoring of the nutritional status of cows with changes within a set of parameters describing the milk production and quality.

This approach provided evidence that moving to summer farms and adapting to the new environment and to pasture is a stressful period for cows, affecting milk yield and composition as well as body fat reserves. These negative changes are greater with cows moved during the first stage of lactation and cows of specialised dairy breeds, particularly Holstein Friesians, than cows of dual-purpose or local hardy breeds. In the final part of the period on summer farms, milk production was similar across breeds, and recovery of milk yield after returning to the permanent farms was also similar. Holstein cows had similar yields, but lower milk quality and lower body condition compared with Brown Swiss and Simmental cows, and especially local dual-purpose breeds (Alpine Grey, Rendena and crossbreeds) making evident their lower adaptability to Alpine pasture.

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