

PAPER

Effect of summer grazing on welfare of dairy cows reared in mountain tie-stall barns

Mirco Corazzin, Edi Piasentier,
Simonetta Dovier, Stefano Bovolenta

Dipartimento di Scienze Animali,
Università di Udine, Italy

Abstract

Traditional mountain farms have an important economic, social and environmental role. The Alps management system for dairy cows consists of animals kept indoors from autumn to spring, mostly in tie-stalls, and moved to mountain pasture in summer. The aim of our study was to assess the effect of mountain summer grazing on the welfare of dairy cows housed in tie-stall barns. Twenty-four farms were considered. In twelve of them, animals were reared in tie-stalls and moved to mountain pasture for three months in summer; they were visited three times: (i) four weeks before grazing during the indoor period in the stall; (ii) about three weeks after the start of grazing; and (iii) in the stall, in autumn, at least three weeks after returning from grazing. The other twelve farms kept the animals in tie-stalls all year; they were visited once in autumn. Data were collected following a protocol that considers animal-based measures and structure information on the basis of Quality Welfare Consortium® indications. Data allowed the calculation of both the Animal Needs Index score (ANI 35L) and an overall assessment of the cows' welfare obtained from three general aspects: housing, animal's physical condition, and animal's behaviour. Summer grazing had a significant positive effect on injuries, lameness and animal's rising duration but a negative effect on faeces consistency. Moreover, a reduction of tongue playing was observed. The ANI 35L and the overall assessment did not show significant differences linked to summer grazing, which tended to have a positive but temporary effect on animal behaviour.

Introduction

Today mountain farms have an economic function as well as a key role in local tourism

promotion, agro-ecosystems conservation, biodiversity preservation and historical traditions maintenance, reflecting a long-term interaction of humans with the fragile mountain environment. However, because of unfavourable natural conditions and world-wide market competition, mountain farms are less competitive and have higher production costs than lowland intensive ones. For these reasons, the European Union not only recognises the need to prevent the abandoning of mountain farms but also proposes their environmental and animal friendly development (European Parliament, 2001).

The traditional Alps management system for dairy cows consists of animals kept indoors from autumn to spring, mostly in tie-stall barns, and moved to mountain pasture in summer. In many mountain regions in Italy, such as Trentino Alto Adige and Valle d'Aosta where important traditional cheeses are produced, tie-stall barns represent more than 98% of the total barns (ISTAT, 2005). In Europe, the percentage of dairy cows reared in tethered houses at least during the winter period reaches the value of 80% in uplands (Veissier *et al.*, 2009b). Leach *et al.* (2009) reported that approximately 88% of Norwegian dairy cattle and 75% of Swedish dairy cows are kept in tie-stalls.

Authorities and consumers show an increasing interest in animal welfare themes (Eurobarometer, 2007). Moreover, it is also considered one of the most important subjects of European policies and its rule implementation is still in the process (Veissier *et al.*, 2008a). Indeed, the standing committee of the European Convention for the Protection of Animals kept for Farming Purposes, in the draft number six, "Draft revised recommendation concerning cattle", proposed to the European Commission on 6th February 2009, suggested that cows would graze for at least 90 days per year, the construction and renovation of tethered houses would be prohibited and daily exercise for animals must be guaranteed in every case.

Many studies have suggested that pasture is beneficial for cows' welfare because it allows the reduction of hock damage, lameness and claw disorders (Leaver, 1988; Loberg *et al.*, 2004; Hernandez-Mendo *et al.*, 2007). In general, grazing seems to be advantageous for cows' welfare (Ketelaar-de Lauwere *et al.*, 1999). Boyle *et al.* (2008), in a recent research report, highlighted that intensive housing systems could be associated with many behavioural problems; however, extensive breeding could also cause poor welfare conditions if not properly managed (Bertoni and Calamari, 2001).

Corresponding author: Prof. Stefano Bovolenta, DIAN, Facoltà di Medicina Veterinaria, Università di Udine, via Sondrio 2, 33100 Udine (UD), Italy
Tel. +39.0432.558170 - Fax: +39.0432.558199.
E-mail: stefano.bovolenta@uniud.it

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The role of tie-stalls in animal welfare is controversial; indeed, Rousing *et al.* (2004) suggested that loose-housing systems allow the animals the possibility to express natural behaviour more than does tie-housing. Moreover, Bielfeldt *et al.* (2005) in a study that involved 4621 cows in 290 different herds found that lameness was observed most frequently in cows housed in tie-stalls without exercise. On the other hand, in an epidemiological survey that involved 80 French dairy farms, Faye and Lescourret (1989) found that cattle housed in free-stalls had a higher incidence of foot disease than cattle in tie-stalls. Loberg *et al.* (2004) reported that the cows are motivated to walk only to get access to food, resting place or social contact. Veissier *et al.* (2008a) did not find any acute or chronic physiological stress response in cows kept under a tethered housing system.

Many methods were proposed for assessing animal welfare at the farm level. The Animal Needs Index score (ANI 35L) (Bartussek, 1999) is based on environmental conditions and attributes high and positive scores to pasture. This index has a high repeatability between evaluators and is objective (Amon *et al.*, 2001). Welfare is a multidimensional con-

cept (Webster, 1994) and it is hard to assess it without directly considering the animals and their attempt to cope with the environment (Broom, 1991). Instead, other methods described by Capdeville and Veissier (2001) and by Whay *et al.* (2003) consider direct observations of animals. However, environmental and animal-based criteria should be included together in an appropriate index for the welfare assessment, as proposed recently by the Welfare Quality® Consortium (Welfare Quality®, 2009).

The aim of this study was to investigate the effect of summer grazing on the principal parameters of animals' welfare and on the physical condition and behaviour of dairy cows reared in mountain tie-stall barns.

Materials and methods

Experimental design

During the year 2008, 24 tethered houses located in the Eastern Italian Alps at a minimum altitude of 600 m were considered. In 12 of them the animals were housed in tie-stalls from autumn to spring and maintained day and night on mountain pasture for 93±6 days (mean±standard deviation) in summer. Each farm was visited three times: about four weeks before summer grazing during the indoor period in the stalls (BG), about three weeks after the start of summer grazing (DG), and in the stalls in autumn at least three weeks after the end of summer grazing (AG). In the other 12 farms the animals were kept in tie-stalls all year (NG) without any exercise and were visited once during autumn. All the visits, for three hours each, were performed about three hours after milking by two independently trained evaluators.

All farms bred at least 10 lactating cows and the breeds reared were Italian Simmental and Italian Brown. The main characteristics of farms and animals at the start of the study were: utilised agricultural area, 40.1±23.5 ha (mountain pasture excluded); number of lactating cows, 19.4±11.5; days in milk, 181.3±35.8; milk yield, 14.5±3.9 kg head/d. The mean characteristics of milk, expressed as the mean value of the 12-monthly surveys before the beginning of the study, were: fat, 3.90±0.43%; protein, 3.31±0.16%; lactose, 4.93±0.18%; and urea, 26.59±8.25 mg/100 mL.

Welfare assessment

The welfare assessment was performed using a protocol (Corazzin *et al.*, 2008) that

takes into account the principal indications of methods used by the Welfare Quality® Consortium (Welfare Quality®, 2009), deepening pasture theme. In particular, three principal aspects such as housing, animal's physical condition and animal's behaviour were considered. These aspects were described by criteria that were quantified by specific measures as shown in Table 1.

Housing measures and observations were assessed following Bartussek (1999). The aspect housing comprised the four criteria (movement, social contact, quality of flooring and stable climate) of the ANI 35L, excluding

the score related to alpine pasture and adding the new criterion of pasture, which was composed of the following measures: transport condition, slope, social structure of the mountain herd, shadow area, stocking density and supplementation. The main part of the measures composing the aspect housing derived from the aggregation of several parameters as reported by Bartussek (1999) for the calculation of the ANI 35L. Moreover, in addition to these parameters to better understand the link between housing measures, management system and direct observations on animals, other measures were collected as reported by Mattiello *et al.*

Table 1. Structure of the overall welfare assessment used to highlight the effect of pasture on animal welfare.

Principal aspects	Criteria	Measures	Score (min-max)	
Housing	Movement	Space allowance	0.0-6.0	
		Outside yard	0.0-6.0	
		Rising, lying down in loose housing	0.0-3.0	
		Tied housing	0.0-2.0	
	Social contact	Social structure of herd	-0.5-2.0	
		Integration of followers	-0.5-2.0	
		Quality of flooring	Resilience of lying area	-0.5-2.5
	Cleanliness of lying area		-0.5-1.0	
	Slip resistance of lying area		-0.5-1.0	
	Floor condition, movement area		-0.5-1.0	
	Floor condition, exercise area		-0.5-1.5	
	Stable climate		Light	-0.5-2.0
			Air quality	-0.5-1.5
		Draughts within lying area	-0.5-1.0	
		Technical noise	-0.5-1.0	
		Days outside/year	0.0-2.0	
	Summer grazing	Hours outside/day	0.0-2.0	
		Transport condition	-1.0-1.0	
		Pasture slope (mean)	-1.0-1.0	
		Social structure of mountain herd	-1.0-2.0	
Shadow area		-0.5-1.0		
Stocking density and concentrates		-1.0-2.0		
Physical condition		Management	Body condition score	-2.0-7.0
	Claw conformation and lameness		-0.5-2.5	
	Somatic cell count		-2.0-5.0	
	Health	Open shoulder	-0.5-2.5	
		Hairless patches	-0.5-2.5	
		Injury	-0.5-2.5	
		Nose and eye discharge	-0.5-2.5	
		Vulvae discharge	-0.5-2.5	
		Cough	-0.5-2.5	
		Soft faeces	-0.5-2.5	
Behaviour	Fear	Avoidance distance	-2.0-5.0	
		Stereotypy	Water lapping	-0.5-3.0
	Tongue rolling		-0.5-3.0	
	Rising		Incorrect rising	-2.0-6.0
		Attempts at rising	-0.5-3.0	
	Lying down	Rising duration	-0.5-3.0	
		Incorrect lying down	-2.0-6.0	
Lying down duration		-0.5-3.0		
Sum of points			-26.5-100 ¹	

¹Maximum column sum of points differs from overall sum because loose housing and tied housing are mutually exclusive.

(2005): feed trough characteristics, stall dimension and chain length.

The physical condition and behaviour of the cows were assessed on 80% of cows per farm (min 71%; max 100%) excluding animals near giving birth and dry (not milking). Considering the difficulty of observations, rising and laying down duration were evaluated on about 40% of cows (min 30%; max 71%). The physical condition of the animals was evaluated using two criteria: management and health. The first one comprised measures of body condition score (BCS), claw conformation and lameness, milk somatic cell count (SCC) and open shoulder. The second criterion comprised measures of hairless patches, injuries, nose, eyes and vulvae discharge, cough and soft faeces. BCS was assessed as proposed by the Welfare Quality® Consortium (Welfare Quality®, 2009). The claw conformation (expressed as a proportion of cows with signs of poor claw conformation per farm) was evaluated using the measures proposed by Boelling and Pollott (1998) and Boelling *et al.* (2001) regarding space between claws, bearing surface, length, shape and angle to the ground. If two or more measures differed from the normal condition, the claw was considered not suitable; if at least one limb observed was not appropriate, the animal was considered to have poor claw conformation. The SCC of each dairy cow was carried out with Foss-o-Matic apparatus (Foss Electric), and the mean value per farm was calculated and expressed as the mean of 12-monthly surveys recorded before the beginning of the study. The other measurements of the second criterion were expressed as a proportion of cows with signs of each condition per farm. Open shoulder is defined as an abnormal shoulder conformation resulting from loose ligaments holding the shoulder blade to the chest. Observing the side of one animal from a maximum distance of two metres, the number of hairless patches or injuries reaching a minimum size of 5 cm was recorded. At the pasture, the lame cows were recorded through the application of a locomotion score proposed by Sprecher *et al.* (1997) and modified by Breuer *et al.* (2000); the animals were divided into two groups – not lame and lame – while observing the regularity of walking movements and the animals' reluctance to support the limb. In the tie-stalls, the lame cows were identified with the method proposed by Leach *et al.* (2009). The faeces defined as soft corresponded to a score ≤ 2 of the scale proposed by Skidmore *et al.* (1996).

The behaviour of the animals was evaluated using four criteria: fear, stereotypy, rising and lying down. The first criterion was measured

by the avoidance distance at the feeding rack; the second is described by the presence of cows with abnormal behaviours such as tongue rolling and water lapping. The criterion rising was evaluated by the incorrect rising, the number of attempts to rise and the duration, while the criterion lying down comprised incorrect movement and related duration. The avoidance distance at the feeding rack was measured as proposed by Welfare Quality® Consortium (Welfare Quality®, 2009); the objective was to highlight the relationship between stockman and animal. Water lapping, expressed as the proportion of cows with signs of water lapping per farm, consists of repeated licking at water without drinking (Albright and Arawe, 1997). Tongue rolling, expressed as the proportion of cows with signs of tongue rolling per farm, consists of repetitive and circular movements of the tongue in and out of the mouth, without the presence of solid material, for more than one minute (Fraser and Broom, 1998). Rising movement was considered incorrect when the cow gets up first with anterior then posterior limbs and it was expressed as the proportion of cows with signs of incorrect rising movements per farm. The attempts to rise were described as the number of attempts by the animals before reaching the standing position. Rising duration was recorded starting when the animal begins to extend the rear limbs and ending when the animal has reached the standing position. The lying down movement was considered incorrect when the animal lies down first with the posterior then anterior limbs and was expressed as the proportion of cows with signs of incorrect lying down per farm. The duration of lying down movements begins when the carpal joint is folded and lowered (before it touches the ground) and ends after the rear limbs touch the ground and are extracted from under the animal's body.

The measures shown in Table 1 were combined with the aim to evaluate the overall effect of pasture on welfare of dairy cows kept in tie-stalls. In particular, three principal aspects of animal welfare were considered: housing, physical condition and behaviour. Within these principal aspects, 11 criteria and 40 measures were assessed. Each measure, recorded on the farm level, can be graded up to the range of score reported in Table 1. The rules previously proposed by Capdeville and Veissier (2001) were considered when assigning a score to each farm for each measure. The range of scores given to each measure meets the need to maintain the same ranges provided by the ANI 35L (Bartussek, 1999) for the criteria movement, social contact, quality of floor-

ing and stable climate and to assign the same weight to each principal aspect. To obtain a single score for each aspect, the different measures and criteria were combined following the logical rules proposed by Capdeville and Veissier (2001), which allowed limiting of their compensation. The overall score of animal welfare per farm was calculated as the sum of the scores of the three aspects. The sum of all possible scores ranged over 126.5 points, from -26.5 to 100 points.

Statistical analysis

The data collected by the two independent evaluators were averaged and, with the exception of continuous variables, were coded as binary or discrete variables and expressed as the proportion of cows with signs of each condition per farm. The statistical analysis was performed using SPSS for Windows, version 7.5.21, Inc 1989-1997.

The variables were subjected to analysis of variance by one-way ANOVA to independently compare the NG farms with the grazing ones in the stage AG. The comparison NG with BG was not considered so as to avoid confounding effects such as season. Instead, the comparisons among BG, DG and AG were analyzed using the general linear model (GLM) repeated measures procedure with time (before, during and after grazing) as within-subject factors. For simultaneous pair-wise comparisons, the least significance differences (LSD) test was chosen.

In the statistical model the breed effect was considered initially; however, it has not been presented or discussed in this paper because it never reached a level of significance. The differences between the farms BG, DG and AG regarding housing, physical condition, behaviour and global score were carried out using the Friedman test, and data were also analysed by the Wilcoxon matched pairs test with Bonferroni adjustment as the post hoc test as suggested by Daniel (1978). The difference between AG and NG was tested with the Mann-Whitney U nonparametric test. Pearson correlation coefficients were used to examine the relationship among different measurements on the farm level and only correlations significant at $P < 0.01$ were considered.

Results and discussion

Recorded data allowed us to calculate the ANI 35L, an index already validated in mountain organic farms (Amon *et al.*, 2001), to analyse animal welfare considering a single measure and to obtain an overall welfare assessment.

Animal Needs Index 35L

The experimental farms showed a relatively restricted range of scored points of the ANI 35L (Bartussek, 1999) (Figure 1). The score range (min 14.0; max 24.0 points) was similar to ranges reported by Ofner *et al.* (2003) and Seo *et al.* (2007) for dairy tethering systems in Austria and Japan, respectively. The mean score for farms with summer grazing was 20.9±2.22 points; the score for farms without summer grazing was 17.3±2.46 points, with no statistical difference between these two groups. In addition, Seo *et al.* (2007) found higher scores for tie-stall barns with an outside area compared to tie-stall barns without an outside area. This is a result of the point scoring system used, which attributes higher values to farms with an outside area or summer pasture not considering the quality of outside management.

Farms were further classified according to six welfare categories corresponding to different grades of good or poor animal welfare (Bartussek, 1999). The number of farms studied for a single category was: 3 for scarcely suitable category (11-15 points), 14 for little suitable category (16-20 points) and 7 for fairly suitable category (21-24 points). In Austria, the standards for organic dairy production were defined on the basis of the above categories and official minimum thresholds of 21 points were established for an existing stable and 24 points for new or reconstructed ones. More than a quarter (7) of the farms investigated reached a score greater than 21 points and 2 equal to 24 points.

Housing

The greatest number of the studied farms had two-stall rows with animals ordered head-to-head (n=8) or back-to-back (n=12). The remaining farms had one-stall rows with feed troughs placed by the wall. The main housing elements influencing animal welfare in tethered houses are stall and feed trough characteristics. In our study, the mean (min; max) value of stall width was 1.12 m (0.80 m; 1.75 m) and of stall length was 1.72 m (1.50 m; 2.00 m). The tie-stall width and length recommended by the codes of practice for handling dairy cattle (Zurbrigg *et al.*, 2005) were 1.20 m and 1.60 m, respectively, referred to a dairy cow of 600 kg of body weight.

Incorrect stall sizes reduce animal welfare; in fact, a short stall may be responsible for abnormal rising behaviour (Chaplin and Munksgaard, 2001) and a narrow stall for decreasing lying duration (Maton *et al.*, 1985). In addition, the stall floor is a significant hous-

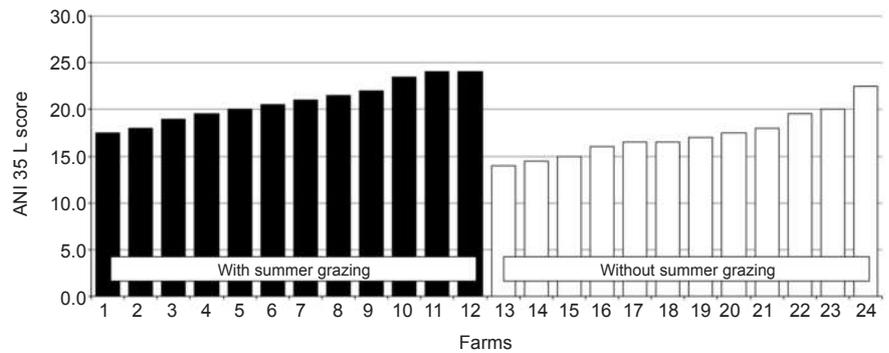


Figure 1. Classification of farms on the basis of the ANI 35L score.

ing element linked to animal welfare. All stables had a stall with a concrete floor and the amount of litter (mainly straw or sawdust) was often limited and cannot guarantee adequate comfort to animals, thus reducing lying duration (Maton *et al.*, 1985).

Another important housing element is feed trough shape. In our study the mean (min; max) value of the feed trough wall height was 0.35 m (0.15 m; 0.65 m); it was higher than the recommended value of 0.20 m (Bovagne and Frayer, 1998). Moreover, the mean (min; max) feed trough height from the stall platform was 0.17 m (0.00 m; 0.40 m). A trough wall that is too high may cause a higher rising duration and incorrect rising movements, such as animals lifting up the front limbs before the back (Albright and Arawe, 1997). Water provision was never limited so animal requirements were satisfied on all farms. Housing characteristics were comparable to those of similar surveys carried out in dairy tie-stall barns in the North Italian mountains (Mattiello *et al.*, 2005).

Physical condition and behaviour of animals

With the aim to evaluate the effect of pasture on dairy cows' welfare, parameters related to physical condition and behaviour of animals were considered. It is widely accepted that BCS is an important indirect measure of cows' energy balance, and it is influenced by many factors such as: poor roughage quality or concentrate level, stocking density, stress linked to transport of animals from valley to mountain farms, the increasing of thermoregulatory and physical activity, or lactation stage (Zemp *et al.*, 1989). Cows were in mid-lactation at the beginning of the study, so during the summer grazing all the animals should have restored body reserves (Berry *et al.*, 2001; Bovolenta *et al.*, 2009). However, this statement was not

observed in the study; indeed, there were no significant differences among BG, DG and AG (Tables 2 and 3). Shortage of differences in our results was probably because of the assessment method, which divides animals into three categories only (thin, normal and fat); consequently, we were not able to markedly highlight differences between all the experimental factors. This statement is supported by the paper of Trachsel *et al.* (2000) that evaluated the BCS in 152 Swiss organic farms with a total number of more than 1600 dairy cows. The authors found a significantly lower BCS in summer than in winter in supplemented cows but with a very small proportion of cows that had a score below 2 or above 4.

The claw measurements and conformation were suggested long ago as an important factor for increased animal longevity and lifetime performance (Distl *et al.*, 1990). In our investigation, as shown in Tables 2 and 3, poor claw conformation was higher in BG than DG and AG (P<0.05). Summer grazing on mountain pasture was an important motivation for improving and trimming claws by the breeders, with relevant effects on animal welfare. Indeed, claw trimming can aid the prevention of lesions for a period of 6-8 months (Fjeldaas *et al.*, 2006). Recently, Loberg *et al.* (2004) suggested that both exercise and the quality of the floor influence claw conformation; in particular, they showed that cows not exercised had significantly longer and lower-angled claws in comparison to cows exercised once a day or once a week. In our study this effect was confounded by claw trimming. However, a correlation (r=0.346, P<0.01; data not reported in Tables) was found between poor claw conformation and lameness. These results do not agree with the findings of Fjeldaas *et al.* (2006) in which the percentage of lame cows did not differ in herds with or without routine trimming in 54 Norwegian tie-stalls and 1100 cows.

The SCC in milk was similar between the two groups of farms, with or without summer grazing. In our study the mean (min; max) value was 308,000 (94,000; 657,000) cells/mL. A value of SCC lower than 100,000 cells/mL reflects a healthy mammary gland, whereas a value higher than 200,000 cells/ml could be a result of many factors, such as bacterial infection, physiological stress and methods of milk storage (Bradley and Green, 2005).

A particularly high mean value (29%) of animals with open shoulder was found, probably because of the housing system and high replacement age of cows: 8.5 years on average (min 5.5; max 11.0) for farms with summer grazing and 6.5 years on average (min 4.5; max 8.5) for farms without summer grazing.

The proportion of cows with hairless patches per farm tended to be higher in AG than DG (P=0.09) (Tables 2 and 3), while no differences were found comparing BG with DG, BG with AG and AG with NG (Tables 3 and 4). In our study 18.6% of animals had at least one hair loss patch. Busato *et al.* (2000) reported hairless spots prevalence in dairy cow soft tissue and joints of 10.9% and 7.3%, respectively, considering different housing systems (free and tethered).

Animals' injuries are an important welfare parameter because they reflect the interaction between environment and dairy cow, and higher values have been found in the tie-stall system (Krohn and Munksgaard, 1993). In general, injuries are the consequence of space restrictions, inadequate stall surface and conflicts between animals (Irps, 1983). In our investigation the stalls had concrete floors with a small amount of straw or sawdust, evenly distributed between experimental groups. The proportion of cows injured per farm was lower for AG than DG (P<0.05); however, no significant difference was found between AG and BG and between BG and DG (Tables 2 and 3). It appeared that three weeks of grazing were not enough to reduce animals' injuries; nevertheless, considering the difference between AG and DG (P<0.05) that reflected, for this parameter, the whole grazing period, it seems that mountain grazing had a positive effect on animals' injuries. There were also significant differences between AG and NG (P<0.05, Tables 2 and 3). Keil *et al.* (2006) suggested that outdoor exercise for more than 50 h in a four-week period reduced the prevalence of hock lesions of dairy cows kept in tie-stalls. In our study the mean value of animals with injuries recorded in stalls was 26.9%.

Lameness is very important for animal welfare because it is considered one of the major problems for dairy cattle that can cause stress,

Table 2. Mean values of animal's physical condition and behaviour parameters recorded in tie-stall barns before summer grazing, during summer grazing, after summer grazing and in other tie-stall barns without summer grazing on mountain pasture.

Parameters of animal welfare	Pasture			
	BG	DG	AG	NG
Physical condition				
BCS*, units	0.89	1.02	0.99	1.08
Poor claw conformation°, %	27.3	8.8	10.1	25.6
Hairless patches°, %	16.4	11.6	21.1	18.2
Injured°, %	24.2	35.2	15.0	41.5
Lameness°, %	12.4	5.2	13.5	15.1
Nose discharge°, %	0.4	0.0	0.3	2.9
Cough°, %	5.6	0.3	7.9	2.8
Vulvae discharge°, %	6.3	2.9	14.3	6.2
Soft faeces°, %	0.7	17.8	0.5	0.8
Behaviour				
Tongue playing°, %	6.0	0.0	4.3	1.5
Incorrect rising°, %	24.8	22.8	29.1	3.6
Rising duration, sec	6.6	4.9	5.9	6.4

BG, before summer grazing; DG, during summer grazing; AG, after summer grazing; NG, without summer grazing. *Molvany score modified: 0 = too thin; 1 = normal; 2 = too fat; °proportion of cows with signs of each condition.

Table 3. Statistical significance of animal's physical condition and behaviour parameters recorded in tie-stall barns before summer grazing, during summer grazing, after summer grazing and in other tie-stall barns without summer grazing on mountain pasture.

Parameters of animal welfare	BG vs. DG ¹		DG vs. AG ¹		BG vs. AG ¹		AG vs. NG ²	
	P	SEM	P	SEM	P	SEM	P	SEM
Physical condition								
BCS	ns	0.107	ns	0.084	ns	0.083	ns	0.066
Poor claw conformation	<0.01	4.773	ns	4.248	0.03	6.961	0.03	3.778
Hairless patches	ns	3.500	0.09	5.148	ns	2.914	ns	3.200
Injured	ns	9.179	0.03	8.204	ns	5.620	0.01	5.000
Lameness	<0.01	2.113	0.09	4.545	ns	3.444	ns	1.988
Nose discharge	ns	4.383	ns	0.269	ns	0.535	0.08	0.713
Cough	0.07	2.651	0.03	2.924	ns	2.113	ns	1.717
Vulvae discharge	ns	3.871	0.03	4.750	ns	4.650	0.06	2.061
Soft faeces	0.04	7.201	0.02	6.213	ns	0.956	ns	0.464
Behaviour								
Tongue playing	0.07	3.031	0.06	1.978	ns	2.303	ns	1.052
Incorrect rising	ns	16.39	ns	9.951	ns	10.17	0.06	3.815
Rising duration	0.09	0.865	ns	0.631	0.02	0.358	ns	0.244

BG, before summer grazing; DG, during summer grazing; AG, after summer grazing; NG, without summer grazing; ns, not significant; ¹differences tested with repeated measure procedure; ²differences tested with one-way ANOVA procedure.

Table 4. Score (mean±standard deviation) of housing, animal's physical condition, behaviour and global welfare assessment recorded in tie-stall barns before summer grazing, during summer grazing, after summer grazing and in other tie-stall barns without summer grazing on mountain pasture.

Parameters of animal welfare	Pasture			
	BG	DG	AG	NG
Indices				
Housing	13.1±2.49	-	13.1±2.49	11.6±2.80
Physical condition	5.6±5.31	7.4±3.97	4.8±3.61	5.7±4.00
Behaviour	13.6±5.39	18.0±5.62	13.3±4.02	17.5±6.27
Global	32.3±7.18	-	31.2±6.42	34.2±9.28

BG, before summer grazing; DG, during summer grazing; AG, after summer grazing; NG, without summer grazing.

pain and discomfort of long duration. As shown in Tables 2 and 3, after three weeks of grazing there was a reduction in lame animals; however, this effect is limited to the grazing period - there were significant differences between BG and DG ($P<0.05$). DG tended to be lower than AG ($P=0.09$) and similar values between BG and AG were found. However, the method used to assess the lameness in tied cows has lower sensitivity compared to the locomotion score (Leach *et al.*, 2009) and it probably caused an underestimation of the prevalence of lameness in tied cows. The real difference between tied and grazing cows is therefore likely to be greater than the difference described in this study. Moreover, there were no differences between NG and AG, with a general mean value of 13.6% of lame tie-cows recorded in the indoor condition (Tables 2 and 3). In addition, Bieldfeldt *et al.* (2005) found an animal lameness prevalence of 13.2% considering 82 farms with tie-stall barns without exercise. Regula *et al.* (2004) in a wide two-year survey on welfare of dairy cattle in Switzerland reported lameness prevalence between 12 and 21%, recorded in tie-stall barns with regular outdoor access and with minimal outdoor exercise during the year. Many authors suggest that regular outdoor exercise can reduce lameness in cows kept in tie-stalls (Regula *et al.*, 2004; Veissier *et al.*, 2008b; Olmos *et al.*, 2009) and prevalence of lameness is low during the grazing season (Leaver, 1988). It could be a result of the comfortable surface provided by pasture (Hernandez-Mendo *et al.*, 2007) that allows a longer and more undisturbed lying duration for the animals (Olmos *et al.*, 2009). Moreover, Bieldfeldt *et al.* (2005) highlighted that exercise favours the improvement of the horn-producing area owing to a higher blood flow in the claw.

Nose discharge was not influenced by the mountain grazing or housing system and only a small, but not significant, difference was found between AG and NG ($P=0.08$) with a mean value of 1.2% (Tables 2 and 3). Instead, coughing was low during grazing; DG was lower than AG ($P<0.05$) and tended to be lower than BG ($P=0.07$) (Tables 2 and 3). However, no differences were found between NG and AG (Tables 2 and 3), with a mean value of 5.4% recorded in the indoor condition. Instead, ocular discharge (data not reported in Tables) was similar among the experimental groups with a very low mean value of animals affected (1% in the indoor condition and 1.5% during grazing). These results only partially agree with the findings of Regula *et al.* (2004) who considered these parameters together for assessing the animal's respiratory disease. In particular,

they did not find any difference for this parameter among three breeding systems: tie-stall with minimal outdoor access, tie-stall with regular outdoor or pasture access and loose housing.

Vulvae discharge is an important parameter used to evaluate reproductive disorders (Welfare Quality®, 2009). In our investigation grazing activity seemed to increase this parameter; it was higher for AG than DG ($P<0.05$) and tended to be higher for AG than NG ($P=0.06$) (Tables 2 and 3). The result is not in agreement with the findings of Brunn *et al.* (2002) who, considering a Danish herd of 2142 with a total of 102,060 dairy cows and collecting data with a questionnaire conducted as a telephone interview, suggested that reproductive disorders were lower in grazing herds. They explained the result with the better musculature condition and health as a result of grazing.

During the grazing period, dairy cows showed a higher level of soft faeces; DG was higher than BG and higher than AG ($P<0.05$) (Tables 2 and 3). However, this parameter did not vary during the indoor housing periods (Tables 2 and 3). It could be because of the fast change from dry forage to herbage, so animals were subjected to the high concentrations of rapidly fermentable carbohydrates in pastures that increased the passage rate of feed material through the rumen, as previously reported in the grazing condition by Oshita *et al.* (2008).

Regarding animal behaviour, the avoidance distance at the feeding rack is an indicator of the quality of the relationship between animals and breeders because it reflects previous experience of cows with humans. In our study this indicator (data not reported in Tables) did not vary during the indoor housing periods with a value of 21.2 ± 17.48 cm. This particularly low value suggests that cows did not have a fear of humans. Tongue rolling is an abnormal behaviour that can be a result of many factors such as nutrition, suckling, oral activity and housing system (Seo *et al.*, 1998). In our study, during the grazing period cows showed reduced tongue rolling and this stereotypy tended to be lower for DG than BG ($P=0.07$) and for DG than AG ($P=0.06$) (Tables 2 and 3). No differences were found between NG and AG (Tables 2 and 3). Redbo *et al.* (1993) also reported that tongue rolling increases with tethering after a grazing period probably because of the deprivation of normal feeding behaviour. However, in our investigation the prevalence of animals affected by this stereotypy remained rather low, less than 4%. Another abnormal behaviour is water lapping that can be because of suppressed grazing behaviour and lack of exercise

(Albright and Arawe, 1997). In our study this indicator (data not reported in Tables) did not vary during the indoor housing periods with a very low mean value (2.8%). Mattiello *et al.* (2005), in 47 tie-stall barns, found tongue rolling and water lapping in 32% and 49% of the farms, respectively.

The tie-stall decreases the cow's freedom of movement; however, animals should be guaranteed the possibility of being able to lie down and rise without restrictions (EFSA, 2009a). In our study grazing did not reduce the number of animals with incorrect rising movement and the value remained particularly high, equal to 19.2% of animals in the indoor condition (Tables 2 and 3). The number of animals with incorrect rising movement was low in farms keeping cows in tie-stalls all year, less than 4%, and the value we found in NG tended to be lower than in AG ($P=0.06$) (Tables 2 and 3). These results could pertain to the different length of the chain of the two farm groups; the average chain length in farms with summer grazing was higher than in farms keeping the cows in tie-stalls all year (55.6 vs 98.8 cm, $P=0.06$, data not reported in Tables). Regarding rising duration, it was lower for AG than BG ($P<0.05$) and tended to be lower for DG than BG ($P=0.09$) (Tables 2 and 3). Grazing seemed to have a beneficial effect on animals and this effect was also found in stalls after the grazing period. No differences were found between NG and AG (Tables 2 and 3) regarding the mean number of attempts at rising per animal; a similar value (1.1 ± 0.16) was found between experimental factors (data not reported in Tables). The results are in agreement with Hellgren (2005) who suggested that rising abnormalities are more frequent and severe in the tie-stalls than in loose housing systems; in fact, improperly designed stalls excessively restricting an animal's movement can make normal rising behaviours difficult. In our study a significant correlation ($r=0.383$, $P<0.01$) was found between rising duration and lameness and between incorrect rising and the distance back and forth allowed by the chain to the animals ($r=0.586$, $P<0.01$), but only a moderate correlation ($r=0.270$, $P=0.08$) was found between injuries and incorrect rising (data not reported in Tables). Regula *et al.* (2004) found a positive correlation between abnormal rising and skin injuries ($r=0.4$) and between abnormal rising and lameness ($r=0.2$); also EFSA (2009a) suggested that lameness could compromise normal rising behaviour.

On the other hand, in our study pasture seemed not to influence the duration and the incorrect lying down movement (data not

reported in Tables). These parameters did not vary during the indoor housing periods with a mean value of $3.14 \pm 6.83\%$ and of 5.77 ± 0.87 sec, respectively, for animals showing incorrect lying down movement and for the duration of the lying down movement. These results are in agreement with Loberg *et al.* (2004) who did not find any difference in the duration of lying down movements in tied dairy cattle with exercise every day, two days per week, one day per week or without exercise. Instead, Gustafson and Lund-Magnussen (1995) suggested that daily exercise for tied cows of 0.4-3 km per day during the first or second lactation allows a reduction in the duration of lying down movement in their third to fifth lactations, compared with non-exercised tied cows.

Overall welfare assessment

As shown in Tables 4 and 5, AG and NG farms were similar for housing characteristics, with the obvious difference of the animal's access or not to summer grazing. Recently, EFSA (2009b) highlighted that the risk estimated for locomotion, behaviour problems, fear and pain was higher for cows in tie-stalls than for cows on pasture. Moreover, Gustafson (1993) highlighted that health of tied dairy cows was significantly and positively influenced by regular exercise all year. In our study, as shown in Tables 4 and 5, pasture had no influence on an animal's physical condition except for DG that tended to be higher than AG ($P=0.09$). Instead, the cows during summer grazing had more normal behaviour; this score was higher for DG than BG ($P=0.06$) and than AG ($P=0.06$). However, the management system only slightly influenced animals' behaviour; NG tended to be higher than AG ($P=0.09$; Tables 4 and 5). In this case the beneficial effect of the pasture did not reflect an animal's better behaviour during the indoor period. Veissier *et al.* (2008a) observed that some effects of behaviour frustration, linked to the motivation of cows to walk, were present just after one day of tethering and cows with at least one hour of exercise per day showed the same behaviour as cows kept in a loose housing system. The differences between the welfare level of animals in stalls and during grazing were probably limited by the good adapting of cows to tethering favoured by the high age of animals (Jensen, 1995) and by the fact that cows were experienced with the breeding system. EFSA (2009a) recommended that dairy cows should not be kept in tie-stalls routinely. However, in our study there were no differences in the global score between AG and NG (Tables 4 and 5) or between BG and AG; indeed, in this case, the same housing score

Table 5. Statistical significance of housing, animal's physical condition, behaviour and global welfare assessment recorded in tie-stall barns before summer grazing, during summer grazing, after summer grazing and in other tie-stall barns without summer grazing on mountain pasture.

Parameters of animal welfare	P			
	BG vs. DG ¹	DG vs. AG ¹	BG vs. AG ¹	AG vs. NG ²
Indices				
Housing	-	-	-	ns
Physical condition	ns	0.09	ns	ns
Behaviour	0.06	0.06	ns	0.09
Global	-	-	ns	ns

BG, before summer grazing; DG, during summer grazing; AG, after summer grazing; NG, without summer grazing; ns, not significant; ¹difference tested with Wilcoxon nonparametric test; ²difference tested with Mann-Whitney U nonparametric test.

would be expected. A well-designed tie-stall may be able to limit the physical and behavioural problems linked to an animal's lack of freedom.

Conclusions

It is well known that summer grazing is beneficial for environment, landscape and rural tourism, and responds to the social need to keep local traditions alive. Summer grazing should be considered with a lot of attention without prejudices with respect to animal welfare. Indeed, the results of the current study showed that animals of farms with summer grazing had better claw conformation and fewer injuries, but tended to have higher vulvae discharge and incorrect rising movements than animals kept in tie-stalls all year. On the other hand, considering the farms before, during and after summer grazing, the study showed a beneficial effect of grazing on lameness but negative on soft faeces after three weeks' grazing. Moreover, at the end of summer grazing a reduction of animals' injuries, cough and rising duration and an increase of vulvae discharge were observed. Few differences were found in dairy cow welfare in the indoor condition comparing two management systems, with or without summer grazing. In conclusion, from a general point of view summer grazing has a positive impact on animal behaviour but this beneficial effect is temporary and not maintained during the indoor period.

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