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Evaluating the need for an animal welfare assurance programme in South Tyrolean dairy farming

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ABSTRACT

Animal welfare assurance is of great importance as dairy farming is recently under increasing pressure to meet societal and commercial expectations. Therefore, this study aims to determine the current welfare situation of dairy cattle housed in tie-stalls and free stalls in South Tyrol (Eastern Italian Alps) in order to evaluate the need for establishment of an animal welfare assurance programme. For reasons of research economy, a protocol was used for data collection that would also be applicable for practical use in an animal welfare assurance scheme. Analyses of resource-based and animal-based indicators recorded in 204 farms in North and South Tyrol (1891 dairy cows) reveal some important animal welfare problems mainly related to the provision of resources and the prevalence of skin alterations especially in tie-stall barns, which are still widely spread in mountain areas. Hence, the implementation of an animal welfare assurance scheme is urgently needed to reflect public concerns through regular and standardised monitoring of welfare indicators and continuous encouragement of improvements in dairy cattle welfare towards predefined targets. Concerning tie-stalls, interventions in stall design as well as the selective use of local breeds best adapted to the mountainous conditions appear to be appropriate measures to optimise dairy cattle health and welfare. These findings substantiate the high value of the data that would be collected as part of the assurance programme to gain insights, which could be used in preventive and corrective health plans to improve welfare-friendliness in dairy farming of South Tyrol.

HIGHLIGHTS

- An adverse effect on animal welfare in tie-stalls was pointed out, even though this housing system is still widely spread in the Alpine region.
- An animal welfare assurance programme for dairy cattle is urgently needed in South Tyrol, where some welfare problems currently exist.
- Regular and standardised monitoring of indicators encourages improvements in dairy cattle health and welfare.

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Introduction

In the Alpine region, mountain farms are essential for sustainable development of mountainous area due to their great contribution to ecosystem services such as maintenance of cultural heritage and historical traditions, preservation of agro-biodiversity, and to their economic importance for decentralised settlement as well as tourism promotion (Battaglini et al. 2014). This applies also to dairy farms in South Tyrol (Eastern Italian Alps), which are characterised by small-scale, family-run structures. The most relevant handicap of agriculture is the mountainous terrain that makes up about 94.0% of the total area of South Tyrol (49.0% between 1000 and 2000 m above sea level (a.s.l.), 37.0% even above 2000 m a.s.l.; Autonome Provinz Bozen – Südtirol 2019), because the vegetation period shortens with increasing altitude and the steepness of utilised agricultural areas limits the use of mechanisation and requires manual maintenance (Autonome Provinz Bozen – Südtirol 2009). 70.0% of the dairy farms are run on a part-time basis (Sennereiverband Südtirol 2017), since alpine dairy farming is usually not sufficient as the sole source of income due to the

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farm sizes, the high production costs and the low productivity per cow. In response to environmental and topographical constraints, dairy cows are mainly kept in conventional tie-stalls, although tethering is associated with a critical husbandry situation on animal welfare considerations (Mattiello 2008) regarding the limitation of movement and the consecutive restriction of species-specific behavioural expressions (Veissier et al. 2008a). Various studies (e.g. Regula et al. 2004; Bielfeldt et al. 2005; Mattiello et al. 2009) have already shown a detrimental effect on animal health and welfare in tie-stalls compared to loose housings. This was also substantiated by the European Food Safety Authority Scientific Opinion on Animal Health and Welfare of dairy cows (EFSA 2009). Therefore, there is a minority opinion that is totally against the use of tie-stalls and asks for banning this housing system. Under alpine conditions, however, loose housing systems are generally not profitable and feasible for economic reasons; this financial issue concerning free stalls is aggravated by the fact that they cannot be built on steep mountainsides due to the lack of space and equipment (Popescu et al. 2013) as the same number of dairy cows requires at least twice the space as in tie-stalls. In the light of the growing global attention on farm animal welfare (Thornton 2010), the acceptance of livestock farms is closely linked to the fulfillment of high animal welfare on both consumer and trade sides (EFSA 2015; European Commission 2016). Retailers shall increasingly require their suppliers to provide proof of welfare-friendly food production (Veissier et al. 2008b). In order to meet these attitudes and expectations, pressure exists to establish assurance schemes (Main et al. 2001; Zuliani et al. 2018). This has also been emphasised by the World Organisation for Animal Health (OIE 2015) and the International Organization for Standardization (ISO 2016), as such programmes are beneficial to promote welfare standards above the legal minimum and to give consumers the confidence to buy food products knowing that animals have been reared and kept with respect for their welfare (Compassion in World Farming and OneKind 2012). Indeed, many different programmes (e.g. the Freedom Food scheme in the UK; Main et al. 2001) have therefore been developed to ensure a certain level of animal welfare in food production (Fraser 2006).

As animal welfare assurance is an indispensable prerequisite for future maintenance of traditional mountain farming, the objective of this study is to disclose the current animal welfare situation of dairy cattle in South Tyrol in order to comprehensively evaluate the need for establishing an animal welfare assurance scheme. The prevalence of selected animal welfare indicators was determined in comparison between tie-stalls and free stalls, because tethered keeping of dairy cattle is an alarming item on social and political agendas in these days. In addition, the value of the data collected was examined to gain insights into the improvement of dairy cattle welfare that can be used in preventive and corrective health plans.

Materials and methods

Study area and farms

The study was carried out in the Alps and encompassed the neighbouring regions South Tyrol (Italian Alps, North-Eastern Italy; Autonomous Province of Bolzano) and North Tyrol (Austrian Alps, Western Austria, Tyrol). Actually, the latter was included in the study, because North Tyrolean dairy farmers are partly employed with the South Tyrolean dairy plant in Vipiteno, as their produced milk is processed and refined across borders and finally sold in form of South Tyrolean dairy products.

The recruitment of farms took place through various channels: milk producers were provided with a one-page information leaflet distributed by the South Tyrolean dairy plants all organised on a cooperative basis and farmers interested in participating could approach their responsible dairy plant directly. In addition, a notice was placed describing the project at the 12th annual agricultural conference Südtiroler Berglandwirtschaftstagung in Bressanone in January 2019. Within each cooperative, some farms were included in the study, while it was defined as a guiding criterion that the memberships of each dairy plant should be proportionally reflected in the respective number of participants. Although Bergmilch Südtirol is the largest dairy plant in terms of memberships (Bergmilch Südtirol 2020), it was exceptionally not represented by the highest number of participants in the study due to problems in recruiting volunteers. No further specific criteria were set for participation relating to farm characteristics such as housing structures or management.

In total, 204 dairy farms (93 tie-stalls with a herd size of (mean ± SD) 14.4 ± 7.8 dairy cows; 111 loose housings with a herd size of 23.7 ± 16.5 dairy cows) participated in the study. 180 farms were located in South Tyrol and 24 farms in North Tyrol. Further descriptive data showed that dairy cows of 71 tie-stalls and 75 loose housings had access to alpine pasture during the summer, whereas the farm's individual proceeding (e.g. time interval of grazing) was not considered. About half of the farms ($n = 103$) kept at least two different cattle breeds.

Data collection

For reasons of research economy, data collection was conceptualised as practical as possible in order to enable an exact transfer of the methodology (e.g. sample size per farm and protocol) into the implementation of a potential animal welfare assurance programme in South Tyrol. Therefore, on each farm a sample of ten randomly selected dairy cows including lactating as well as dry cows was assessed once by the same independent observer (in order to obtain homogeneous data) during on-farm visits between March and October 2019. The selection was made in tie-stalls by choosing every second animal, whereas in loose housing systems the animals had to be fixed in the feeding fence before being selected in the same way (Brinkmann et al. 2016). If herd size was equal to or less than ten dairy cows, all animals were considered accordingly. In total, data set comprises 1891 dairy cows (822 cows in tie-stalls; 1069 cows in free stalls) belonging to the following breeds: Bruna (B; *Brown-Swiss*; $n = 645$), Pezzata Rossa (PR; *Simmental*; $n = 512$), Holstein-Frisona (HF; *Holstein-Friesian*; $n = 433$), Grigio Alpina (GA; *Tyrolean Grey*; $n = 204$), Jersey ($n = 37$), Pinzgauer ($n = 20$) and others including crossbreeds ($n = 40$).

Animal health and welfare were monitored by using indicators, which are, following the assessment protocol of the European Union (EU)-founded Welfare Quality project (Welfare Quality 2009), recommended by the German association Kuratorium für Technik und Bauwesen in der Landwirtschaft e. V. (KTBL; Brinkmann et al. 2016). In order to meet the specific operative conditions, e.g. welfare assessment on small-scale farms (EFSA 2015), however, the KTBL guideline had to be reduced and adjusted in terms of scope and time. Therefore, a corresponding assessment protocol for application in an animal welfare assurance programme was developed and elaborated based on trying three different recording methods during pilot visits by a veterinarian in 2018 (same person who also executed the on-farm assessment in 2019). Using exclusively this finalised protocol, the majority of indicators was recorded by direct measurements. In total, ten animal welfare indicators were monitored per farm – mainly animal-based indicators, because they are more closely linked to the welfare of animals and increasingly preferred over resource-based indicators (Whay et al. 2003; EFSA 2012).

Resource-based indicators

To estimate the cows' water provision, water flow rate per minute was measured twice at two randomly selected drinking troughs. In detail, the amount of water outcoming per minute for bowls was checked by filling them up to the brim, collecting the outflow during a time interval of 15 s and multiplying the quantity by four (Brinkmann et al. 2016). In case of automatically regulated troughs, the total filling volume had been calculated before the trough was emptied and the time interval for closing the valve was determined (Brinkmann et al. 2016). Furthermore, the number and dimensions of stalls/cubicles as well as the quality of stall base and bedding material were recorded in order to gain insights into the space and comfort around resting. An overview of these resource-based measures as well as their respective categories assessed at data collection and subsequently retained for statistical analysis is given in Table 1.

Table 1. Overview of resource-based indicators as well as their respective categories assessed at data collection and subsequently retained for statistical analysis.

Indicator	Categories[a]	Retained categories[b]
Water flow rate per minute		
Drinking trough 1	0 – 5 litres; 5 – 10 litres; **10 – 15 litres; 15 – 20 litres; > 20 litres**	< 10 litres; **≥ 10 litres**
Drinking trough 2	0 – 5 litres; 5 – 10 litres; **10 – 15 litres; 15 – 20 litres; > 20 litres**	< 10 litres; **≥ 10 litres**
Number of stalls/cubicles	No categories, metric level	
Dimensions of stalls/cubicles		
Length	No categories, metric level (in metres)	Area, metric level (in square metres)
Width	No categories, metric level (in metres)	
Quality of stall base	Wood; concrete or tiles; rubber mats; **deep-litter stalls/cubicles; compost-bedded pack system** Hard stall base; **soft stall base**	
Quality of bedding material	Straw; straw-lime mixture; sawdust; leaves; manure solids; compost; no bedding	

[a]Categories at the time of data collection: Bold indicates normal category.
[b]Categories retained for statistical analysis, if necessary: Bold indicates normal category.

Table 2. Overview of animal-based indicators as well as their respective categories assessed at data collection and subsequently retained for statistical analysis.

Indicator	Categories[a]	Retained categories[b]
BCS	Very lean; lean; **good**; fat; very fat	**Normal**; abnormal
Avoidance distance	**Cow can be touched**; cow can be approached by distance < 1 metre, but not touched; cow can be approached by distance ≥ 1 metre	**Cow can be touched**; avoidance behaviour
Skin alterations		
Skin alteration on the neck		
Hair loss	**Not present**; present	
Swelling	**Not present**; present	
Lesion	**Not present**; present	
Skin alteration at the knee		
Hair loss	**Not present**; present	
Swelling	**Not present**; present	
Lesion	**Not present**; present	
Skin alteration at the hock		
Hair loss	**Not present**; present	
Swelling	**Not present**; present	
Lesion	**Not present**; present	
Dirtiness		
Dirtiness at the udder	**Clean**; dirty	
Dirtiness at the upper hind leg	**Clean**; dirty	
Dirtiness at the lower hind leg	**Clean**; dirty	
Lameness		
Lameness when standing	**Not lame**; slightly lame; severely lame	**Not lame**; lame
Lameness when moving	**Not lame**; slightly lame; severely lame	**Not lame**; lame
Claw conformation		
Front claw		Front and hind claw
Overgrown claws	**Not present**; present	**Not present**; present
Other claw disorders	**Not present**; present	**Not present**; present
Hind claw		
Overgrown claws	**Not present**; present	
Other claw disorders	**Not present**; present	
Getting up behaviour	**Normal**; repeated attempts to get up; carpal joint position; 'getting up behaviour like a horse'	**Normal**; abnormal
Calving difficulty	**No**; yes	

[a]Categories at the time of data collection: Bold indicates normal category.
[b]Categories retained for statistical analysis, if necessary: Bold indicates normal category.
BCS: Body condition score.

Animal-based indicators

In addition, cow-based indicators (Table 2) were assessed individually for each selected animal identified by ear tag number, based on visual examination at a maximum distance of two metres (Brinkmann et al. 2016). Body condition score (BCS) was scored from behind on appearance of the lumbar region of the vertebral column (spinous processes and transverse processes), tuber coxae (hip or hook bones), tuber ischii (pin bones) and the cavity around the tail head. All factors considered together provided an accurate score based on a five-point dairy scoring system proposed by Wildman et al. (1982). Avoidance distance was estimated as the distance between the assessor's hand and the muzzle of the cow when the observed animal showed the first withdrawal. Definition of withdrawal was when the animal moves back, turns its head to the side or shakes head. To this end, the cow was approached from the front by the rater, who held the arm outstretched at an angle of about 45° in front of the body and slowly walked towards the animal at a speed of one step per second and a step length of approximately 60 cm (Waiblinger et al. 2007; Brinkmann et al. 2016). Further, the presence of skin alterations with a minimum diameter of two centimetres at the largest extent (Brinkmann et al. 2016) was monitored, distinguishing between hair loss, swelling and lesion. Dirtiness was assessed on the basis of the presence of separate or continuous plaques of dirt amounting to at least the size of the palm of the hand per region observed (Brinkmann et al. 2016). Moreover, claw conformation covering the presence of overgrown claws and other disorders, e.g. lesions, ulcers or digital dermatitis, was noted. According to the specifications of the KTBL, skin alterations, dirtiness and claw conformation were examined from one side of the body only, in the present case always from the right side (Brinkmann et al. 2016). Lameness was recorded from behind, whereby the front feet were viewed as best possible. Following the recommendations of Leach et al. (2009) and Welfare Quality (2009) for assessing lameness in cows confined in tie-stalls, the animal was first observed while standing undisturbed. Thereby, lameness was scored on appearance of repeated shifting of weight from one foot to another, rotation of feet from the line parallel to the midline of the body, standing on the edge of a step and resting a foot (one foot more than another). Then the cow was encouraged to move to the left and to the right (applying hand pressure to the hindquarter if necessary), since it was generally not practical to release tied-up animals to carry out gait scoring. When moving from side to side, uneven weight bearing between feet, demonstrated by more rapid movement by one foot to relieve another or reluctance to bear weight on one foot, as well as the position the cow returned to after movement were considered. In free stalls, the same criteria were applied to assess lameness while standing, whereas the cow's step length, head bob and arched back were recorded during gait scoring in the corridors (Brinkmann et al. 2016). All factors considered while standing and moving resulted in two separate scores each based on a three-point scale described by Brinkmann et al. (2016). To observe getting up behaviour, the animal was motivated to stand up by addressing or slightly touching the hindquarter (Brinkmann et al. 2016). In order to enable comparison between tie-stalls and free stalls, loose housed cows were headlocked at the feed bunk during the assessment and only released for examination of lameness (when moving) and getting up behaviour. Finally, calving difficulty occurring during the last six months was evaluated based on farmer's documentations.

For statistical analysis, polytomous variables were consistently calculated as dichotomous measures (normal *vs.* all other categories; Table 2). Further, data on the prevalence of cows showing overgrown claws and other claw disorders were each summarised by including both the front and hind claw (Table 2).

Statistical analysis

The current animal welfare situation of dairy cattle was analysed by determining the prevalence of resource-based and animal-based indicators. In general, resource-based measures were calculated at farm level but cow-based data at animal level. In order to test for significant differences between both husbandry systems, metric data on the area of stalls/cubicles were submitted to non-parametric analysis for mean comparison (Mann–Whitney U test), while we used chi-squared test to compare the observed frequency distributions of dichotomous categorial variables. In addition to the unifactorial analysis, cow-related data were also analysed using Generalised Estimation Equation (GEE) to take into account the drawn cluster sample (i.e. maximum of ten cows per farm) as well as the partial effects of multiple factors (housing system, use of pasture, cattle breed, interaction housing system*pasture).

Focusing on cows observed in tie-stalls, the relationship between resource-based and animal-based indicators was investigated. Therefore, frequency distributions were compared by chi-squared test. Furthermore, breed differences affecting the prevalence of cow-based indicators in tie-stalls were examined. For this reason, four dairy cattle breeds most frequently kept in South Tyrol (Landesinstitut für Statistik ASTAT 2019) were likened: B, HF, PR and GA. The frequency of animals with abnormal BCS, avoidance behaviour, skin alterations (neck, carpal and tarsal joint), dirtiness (udder and hind leg), overgrown claws and other disorders at the claws, lameness (when standing and moving) and abnormal getting up behaviour between each pair of breed was thereby compared by chi-squared test with adjustment for multiple testing according to Bonferroni.

Significant levels were consistently related to $p < 0.05$. Missing values (e.g. when evaluating skin alterations due to high contamination of the animal) were generally not addressed. All described analyses were done using IBM SPSS Statistics 26.

Sample design

The distribution of husbandry systems within the sample is contrary to official data, which show a predominance of tie-stalls for keeping dairy cattle in South Tyrol (Sennereiverband Südtirol 2017). Further, the distribution of farms that used to take dairy cows to pasture is around 70.0%, which corresponds to current figures (Sennereiverband Südtirol 2017). With regard to breed distribution, the sample includes more B than PR, although the latter is most common in South Tyrolean dairy farming (Landesinstitut für Statistik ASTAT 2019). However, distributions of HF and GA are in line with the population (Landesinstitut für Statistik ASTAT 2019). In conclusion, the sample is not representative, and the results cannot be interpreted as valid for the South Tyrolean dairy cattle population. In any case, the sample size covering 4.5% of South Tyrolean dairy farms (Sennereiverband Südtirol 2020) seems suitable for the purpose of this study.

Results and discussion

Resource-based indicators

Analyses of water provision clarified that the water flow rate ≥ 10 l/min required by the KTBL (Brinkmann et al. 2016) was achieved in 71.2% of loose housing systems at both measured water points, whereas the respective percentage was significantly ($p < 0.001$) lower in tie-stalls (38.7%). Concerning tie-stalls, 28.0% of evaluated farms showed a lack at one out of two drinker bowls, while water flow rate was too low in both measurements in remaining stables. As Andersson et al. (1984) acknowledged, provoked drinking behaviour (i.e. either increased frequency or time of drinking) and reduced water intake could be the consequences.

The statistical evaluation of space and comfort around resting showed significant ($p < 0.001$) differences between the systems regarding the average area of stall/cubicle ($2.2 \pm 0.2\,m^2$ in tie-stalls ($n = 93$) *vs.* $2.4 \pm 0.3\,m^2$ in free stalls ($n = 107$)). Of the visited tie-stalls, 2.6% used wood (hard) in the lying down area, 10.5% concrete floor or tiles (hard) and 73.7% conventional hard rubber mats (hard). With the exception of one farm, these permanent stall surfaces were covered with some bedding material (straw, sawdust or leaves). The remaining tie-stalls (13.2%) used deep-litter stalls (straw beds; soft), while deep-litter cubicles (soft) with bedding material, such as straw, straw-lime mixture or recycled manure solids were mainly found in free stalls (81.6%). Accordingly, hard stall bases were significantly ($p < 0.001$) more frequently reported in tie-stalls ($n = 76$) when compared with free stalls (86.8% *vs.* 14.3% in free stalls ($n = 98$)) concluding that resting behaviour in tie-stall barns is more disturbed, since dairy cows show a clear preference, measured by lying time, for soft stall bases (Rushen et al. 2007; Götz 2012). However, a bottleneck was found in 13 out of 111 free stalls (11.7%) as more animals were kept at the time of the on-farm visit than cubicles were provided violating the recommendations of the EFSA (2009).

Animal-based indicators

57.4% of cows showed normal BCS, while the remaining animals mainly drifted towards lean scores (summarising both categories lean (31.1%) and very lean (3.0%)) rather than towards fat scores (summarising both categories fat (7.7%) and very fat (0,7%)). Comparing the present results with outcomes of Mattiello et al. (2009), the overall prevalence of lean animals (34.1%) was higher. Further, there were no significant differences depending on the housing system (Table 3).

Table 3. Prevalence of animal-based indicators in dairy cows housed in tie-stalls (TS) and free stalls (FS).

	Housing system			
Indicator (% of animals)	TS	FS	*p*-value[#]	*p*-value[§]
Abnormal BCS[a]	43.3	42.0	ns	ns
Avoidance behaviour[b]	38.8	54.7	< 0.001	< 0.001
Skin alteration on the neck[a]	45.3	7.4	< 0.001	< 0.001
Hair loss	21.9	5.0	–	–
Swelling	35.6	4.3	–	–
Lesion	0.7	0.7	–	–
Skin alteration at the knee[c]	65.5	35.1	< 0.001	< 0.001
Hair loss	53.2	33.2	–	–
Swelling	32.3	6.6	–	–
Lesion	0.1	0.3	–	–
Skin alteration at the hock[d]	70.3	26.1	< 0.001	< 0.001
Hair loss	69.8	25.8	–	–
Swelling	6.9	1.0	–	–
Lesion	0.7	0.6	–	–
Dirtiness at the udder[a]	11.7	5.0	< 0.001	0.002
Dirtiness at the upper hind leg[a]	24.3	25.2	ns	ns
Dirtiness at the lower hind leg[a]	41.0	51.0	< 0.001	ns
Overgrown claws[e]	44.4	31.8	< 0.001	0.012
Other disorders at the claws[e]	6.7	8.8	ns	ns
Lameness when standing[a]	7.9	5.7	0.046	0.045
Lameness when moving[a]	13.6	11.3	ns	ns
Abnormal getting up behaviour[f]	13.5	8.4	0.01	ns
Calving difficulty[g]	5.6	4.5	ns	ns

[a]TS: $n = 822$; FS: $n = 1069$.
[b]TS: $n = 822$; FS: $n = 1066$.
[c]TS: $n = 773$; FS: $n = 1038$.
[d]TS: $n = 764$; FS: $n = 1042$.
[e]TS: $n = 820$; FS: $n = 1068$.
[f]TS: $n = 519$; FS: $n = 478$.
[g]TS: $n = 818$; FS: $n = 1067$.
BCS: Body condition score.
#Differences tested with unifactorial analysis (chi-squared test).
§Differences tested with multifactorial analysis (GEE).

Cows in free stalls more frequently exhibited avoidance behaviour when compared with cows in tie-stalls (Table 3), which is in agreement with findings of Mattiello et al. (2009). Thus, present results suggest a closer human–animal relationship (HAR) in tie-stalls, possibly due to the animals' habituation to human interactions, as most of work has to be done by hand. As part of the routine management, the stockperson is continuously in visual, tactile and likely vocal contact with each individual cow, e.g. when standing closely between the cows during milking. Close human-animal bond and good stockman ship are of high importance for farm animals' health and welfare also considering the ease of handling and the subsequent decreasing risk of injuries both for cow and human (Waiblinger et al. 2002). Therefore, tie-stalls seem to be advantageous compared to free stalls when discussing animal welfare in context of HAR.

Skin alterations are widely accepted as being painful and a welfare concern (Huxley and Whay 2006). Integument alterations on the neck were more prevalent in animals observed in tie-stalls than in cows kept in free stalls (Table 3) indicating a lack of comfort, i.e. inadequacy of the tethering system. While hair loss is often caused through constant rubbing and chafing of the necklace in tie-stalls, positioning of the tie-rail horizontal above the feed trough may be a trigger for formation of swelling areas when animals push far forward to reach food. Furthermore, skin alterations were more frequently found at the carpal and tarsal joint and there were also significant differences between tie-stalls and free stalls (Table 3). Welfare problems related to the skin integrity of the legs may be due to reduced cow comfort in the resting area, e.g. in response to hard stall bases and limited amounts of bedding material. Similar to the neck area, primarily hairless patch areas and swellings were recorded on the legs, while lesions were generally rarely seen (Table 3).

Against the background that cattle cleanliness affects health conditions in terms of reducing the risk of mastitis (Cook 2002) as well as thermoregulation and hygienic milk production (Reneau et al. 2003; Ruud et al. 2010) udder dirtiness was more prevalent in tie-stalls than in free stalls (Table 3). However, foot and leg hygiene in free stalls was worse than in tie-stalls (Table 3), possibly due to deficient management regarding the quantity of manure present in the alleys depending on, for example stocking density and frequency of corridor scraping, as also Cook (2002) has stated. Regarding the prevalence of cows showing dirt at the lower hind leg, the unifactorial analysis revealed significant differences between tie- and free stalls, while the GEE showed no significance. Accordingly, there was probably only an illusory effect, which was eliminated by multifactorial analysis.

Overgrown claws were more frequently recorded in cows observed in tie-stalls than in free stalls (Table 3), probably influenced by comparatively higher rates of wearing on the claws due to the freedom of movement in the corridors. Inversely, other disorders at the claws were more frequently found in loose-housed cows when compared with cows kept in tie-stalls (Table 3), which is in agreement with findings of Sogstad et al. (2005). Although an unkempt claw conformation affects well-being and production (Alvergnas et al. 2019), maintenance of the claws is quite often neglected and postponed in dairy farms in mountain areas, because farmers usually trim the claws themselves for economic reasons and procedures are extremely time-consuming due to the restricted use of facilitating technologies for more comfortable working (e.g. claw trimming chutes).

The prevalence of cows showing locomotion difficulties was generally higher while moving than while standing (Table 3). There were significant differences between tie-stalls and free stalls when assessing lameness while standing, but not while moving (Table 3). Scientific data on lameness prevalence in European countries range from $< 1.0\%$ to 21.0% for systems, in which cows are tied-up for at least part of the time (Bielfeldt et al. 2005; Sogstad et al. 2005; Zurbrigg et al. 2005), and from 22.0% (Whay et al. 2003) to 45.0% (Winckler and Brill 2004) for loose housing systems. The present results were compared with these references by summarising the data on lameness when standing and moving (14.8% in tie-stalls *vs.* 11.9% in free stalls; ns). While the observed prevalence of lame animals in tie-stalls was in accordance with the literature, the respective percentage in free stalls was below the published range. Additionally, the analysed ratio was contrary to the papered results of higher lameness prevalence in free stalls (e.g. Cook et al. 2004). Notwithstanding this, lameness was more common in both systems than the EFSA recommendation for prevalence $< 10.0\%$ (EFSA 2009).

Further results generally showed a positive effect of mountain pasture on variables related to foot and leg health (Table 4) and, therefore, summer grazing is probably of help to compensate, to some extent, for structural inadequacies in housing. Bielfeldt et al. (2005) and Corazzin et al. (2010) have already acknowledged that claw conformation and lameness may vary in response to different housing systems, especially depending on access to pasture. Even though cows with access to alpine pasture were dirtier than those without outdoor exercise, this was possibly due to the state of the pasture influenced by weather conditions or to changes in feed components resulting from grazing.

Table 4. Prevalence of animal-based indicators related to foot and leg health in dairy cows with summer grazing (SG) and those without grazing (NG).

	Use of alpine pasture			
Indicator (% of animals)	SG	NG	*p*-value[#]	*p*-value[§]
Skin alteration at the hock[a]	43.8	47.2	ns	0.008
Dirtiness at the hind leg[b,d]	53.7	48.3	0.033	0.009
Other disorders at the claws[c]	5.9	12.7	< 0.001	0.018
Lameness when standing[b]	5.1	10.3	< 0.001	0.023
Lameness when moving[b]	10.3	17.2	< 0.001	0.031

[a]SG: $n = 1270$; NG: $n = 536$.
[b]SG: $n = 1338$; NG: $n = 553$.
[c]SG: $n = 1335$; NG: $n = 553$.
[d]Dirtiness at the hind leg was calculated by summarising dirtiness at the upper and lower hind leg.
#Differences tested with unifactorial analysis (chi-squared test).
§Differences tested with multifactorial analysis (GEE).

Table 5. Prevalence of animal-based indicators in four dairy cattle breeds Bruna (B), Holstein-Frisona (HF), Pezzata Rossa (PR) and Grigio Alpina (GA) housed in tie-stalls.

	Breed				
Indicator (% of animals)	B	HF	PR	GA	p-value[#]
Abnormal BCS[d]	52.4[a]	47.9[ab]	33.7[c]	35.8[bc]	<0.001
Avoidance behaviour[d]	42.3	41.3	35.1	33.8	ns
Skin alteration on the neck[d]	61.4[a]	50.9[ab]	45.2[b]	14.9[c]	<0.001
Skin alteration at the knee[e]	66.5[ab]	63.1[ab]	73.5[a]	54.0[b]	0.004
Skin alteration at the hock[f]	67.6[b]	74.5[ab]	84.1[a]	48.9[c]	<0.001
Dirtiness at the udder[d]	10.5[abc]	16.8[ab]	13.9[b]	4.1[c]	0.003
Dirtiness at the hind leg[d,i]	42.7[b]	61.1[a]	53.4[ab]	23.0[c]	<0.001
Overgrown claws[g]	34.2[c]	67.1[a]	35.6[bc]	48.0[b]	<0.001
Other disorders at the claws[g]	7.5	9.0	6.3	4.1	ns
Lameness when standing[d]	7.1[a]	11.4[a]	11.5[a]	0.7[b]	0.001
Lameness when moving[d]	12.4[ab]	17.4[a]	15.9[ab]	7.4[b]	0.043
Abnormal getting up behaviour[h]	13.9[abc]	17.8[ab]	18.1[a]	5.3[c]	0.03

[a–c]Values within a row with different superscripts differ ($p < 0.05$).
[d]B: $n = 267$; HF: $n = 167$; PR: $n = 208$; GA: $n = 148$.
[e]B: $n = 260$; HF: $n = 160$; PR: $n = 200$; GA: $n = 124$.
[f]B: $n = 253$; HF: $n = 153$; PR: $n = 189$; GA: $n = 139$.
[g]B: $n = 266$; HF: $n = 167$; PR: $n = 208$; GA: $n = 148$.
[h]B: $n = 166$; HF: $n = 107$; PR: $n = 127$; GA: $n = 95$.
[i]Dirtiness at the hind leg was calculated by summarising dirtiness at the upper and lower hind leg.
BCS: Body condition score.
[#]Differences tested with unifactorial analysis (chi-squared test).

Cows in tie-stalls more frequently exhibited getting up behaviour in an abnormal way than animals in loose housings (Table 3), which is in accordance with findings of Mattiello et al. (2009) demonstrating that cows in tie-stalls perform significantly more frequently abnormal up and down movements. However, the two statistical methods used in this study showed differences in the results. Thus, there was probably only an illusory effect, which was eliminated by multifactorial analysis (GEE). It must be considered that the assessment of the animals' getting up behaviour was not feasible in an acceptable time frame, if dairy cows to be scored were already standing at the time of the on-farm visit, for example due to feeding or because they expected to go out to pasture soon. Therefore, analyses of this indicator comprise only 997 out of 1891 cows.

The prevalence of calving difficulties was amounted to 5.0% without significant differences between the housing systems (Table 3).

Overall welfare outcome assessment

The values are reflecting the current animal welfare status in South Tyrolean dairy farms, with some important animal welfare problems being identified. Because no specific Directive has been adopted regarding dairy cattle farming so far, the EFSA has issued a Scientific Opinion on request of the Commission (EFSA 2009). Accordingly, non-compliances with recommendations for animal welfare given by the EFSA were found. Disadvantages were pointed out in tie-housings compared to free housing systems mainly related to the provision of resources and the prevalence of skin alterations, thus confirming the published data by Regula et al. (2004), Bielfeldt et al. (2005) and Mattiello et al. (2009). Reacting to this issue, some countries are moving towards abolishing tie-stalls (Leach et al. 2009). In Norway, e.g., it has been prohibited to build new tie-stall barns since 2004 and mandated that all cattle shall be housed in loose housing systems starting in 2024 (Norwegian Food Authorities 2004), while tie-stalls are also becoming scarce in France (French Livestock Institute 2009). Precisely because alpine housing conditions are still most frequently characterised by use of tie-stalls (Sennereiverband Südtirol 2017), the animal welfare state is likely even worse among the population than in the sample. Thus, the South Tyrolean dairy sector is forced to take measures to improve welfare-friendliness. To the best of our knowledge, there has been no welfare assurance scheme for dairy cattle to date in the South Tyrolean private sector, which addresses societal and commercial demands by ensuring producers adhere to standards that define some aspects of animal husbandry (Main et al. 2001), such as provision of resources, management practices, medical records and animal health and welfare state. Therefore, it is highly recommended to establish an animal welfare assurance programme in South Tyrolean dairy farming.

Insights into the improvement of animal welfare in alpine tie-stalls

With special regard to tie-stalls, which are at high risk of specific welfare problems, risk factors of animal welfare were identified by examining the relationship between resource-based and animal-based indicators. Numerous studies have already focused on the relation between environmental factors and knee and hock injuries. In doing so, the effects of short stalls (e.g. Keil et al. 2006), long stalls (e.g. Potterton et al. 2011), restricted lying space (e.g. Regula et al. 2004), small lunging space (e.g. Haskell et al. 2006) as well as hard stall base and bedding (e.g. Rushen et al. 2007; de Vries et al. 2015) were described. Present results were consistent with the literature that the comfort of the lying area is a decisive factor influencing the integrity of the skin in the area of the front and hind legs' joints. Indeed, cows housed in tie-stalls showed significantly ($p < 0.001$) less skin alterations in the presence of deep straw beds when compared with the absence of deep straw beds in the lying down area (in the carpus region 26.5% *vs.* 67.6% ($n = 630$), in the hock region 41.5% *vs.* 75.0% ($n = 618$)). Thus, soft design of stall surface seems to be advantageous to prevent skin damage to the carpal and tarsal joints. The determination of breed differences affecting cow-based indicators also provided useful information for improving animal welfare by focusing on genetics and selective husbandry of those breeds characterised by maximal adaptability according to their environment in mountain areas. Relating to this, Mattiello et al. (2011) published that the breed factor significantly affects the welfare of dairy cows housed in traditional tie-stalls in the Italian Alps, as the prevalence of indicators of poor welfare was lower in local breeds, which are better adapted to the rural conditions. In fact, results of the present study consistently revealed that GA showed a lower prevalence of animal welfare problems compared to B, HF and PR, when kept under restrictive conditions of tie-stall barns (Table 5).

Given these findings on appropriate intervention measures in tie-stalls, data that would be routinely collected as part of the animal welfare assurance scheme recommended here seem to be beneficial to gain insights into the improvement of dairy cattle welfare at farm level. Finally, the application of this data-based knowledge on resources and management in health plans might contribute to the up-to-dateness and image of this antiquated housing system typical for Alpine region and possibly also to its continued acceptance within the broader public. This is closely related to the future maintenance of mountain farming in South Tyrol in terms of cultural heritage and historical traditions, not to mention the numerous workplaces in rural areas.

Conclusions

The establishment of an animal welfare assurance programme for dairy cattle is urgently needed in South Tyrol, as there are currently some existing animal welfare problems. Animal welfare assurance enables a response to public concerns, in particular criticisms of keeping dairy cattle tied-up and, thus, to meet societal and commercial expectations through regular and standardised monitoring of welfare indicators and continuous encouragement of improvements in dairy cattle welfare. Data that would be collected as part of the assurance scheme provide insights into improving welfare-friendliness, which could be used in animal health and welfare planning in dairy farming.

However, future research priorities lie on the precise definition of minimum acceptable levels of animal welfare as well as the practical implementation of welfare outcome assessment on mountain farms to ensure that producers comply with these thresholds. Any scientific approach should be characterised by a deep understanding of the different alpine farming systems, their practices as well as the difficulties they face due to the mountainous terrain.

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Ethical approval

The experimental and notification procedures were carried out in compliance with Directive 86/609/EEC.

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