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# Effect of low and high concentrate supplementation on health and welfare indicators in different breeds in small-scale mountain dairy farms

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### Abstract

We investigated and compared the effects of low and high concentrate supplementation in terms of animal welfare, health and reproductive performance in two different dairy cow breeds on small-scale mountain farms. 64 South Tyrolean dairy farms were evaluated using an on-farm assessment for animal-based and resource-based welfare indicators, data from test day records, and a questionnaire for the farmer. Farms were divided into four groups: low input Tyrolean Grey (L-TG), low input Brown Swiss (L-BS), high input Tyrolean Grey (H-TG) and high input Brown Swiss (H-BS). Effects of intensity level, breed and their interaction were calculated and analyzed statistically. The predominant husbandry system across all groups was tie-stall. The average energy-corrected milk yield increased with increasing concentrate level, with L-TG showing the lowest and H-BS showing the highest milk yield. Age at first calving was lowest in H-BS when compared to all other systems, while numbers of lactations were higher in L-TG compared to H-BS. Feed efficiency (percentage of milk out of roughage) was significantly higher in L-TG and L-BS when compared to H-TG and H-BS. L-BS showed the poorest results for most of the welfare indicators such as lean cows, lesions and percentage of dirty animals. In conclusion, a higher concentrate level in diets does not lead automatically to lower animal welfare for dairy cows in alpine regions. Indeed, keeping high yielding breeds in extensive systems seems to be challenging. The dual-purpose breed TG showed some clear advantages in that calving interval was lower and the number of lactations greater.

In recent years, livestock production is being increasingly criticized and consumers demand more animal welfare-friendly systems (Cardoso *et al*., 2016). Broom (1996) defined animal welfare as the success of an individual in coping with its environment. According to the Farm Animal Welfare Council (1979), the welfare of an animal should always be considered in the light of the 'Five Freedoms', namely freedom from hunger and thirst, freedom from discomfort, freedom from pain, injury and disease, freedom to express normal behavior and freedom from anxiety and stress. Consumers often associate extensive, small-scale, and pasture-based farming systems with benefits when compared to intensive, large-scale dairy production (Fearne and Lavelle, 1996; Weinrich *et al*., 2014). In mountain areas, small-scale dairy farms are still in the majority. South Tyrol (Northern Italy) can be considered as an example for a mountainous region with a traditional dairy production characterized by part-time farmers, small herd sizes and tie stalls (Südtiroler Sennereiverband, 2017). Even though the milk price is higher than in most other European regions (Autonome Provinz Bozen-Südtirol, 2017), farmers here and in other mountain regions face very high expenses for machines and concentrates (Tasser *et al*., 2012) as well as high labor costs (Poulopoulou *et al*., 2018). Thus, the economic situation is the main challenge for traditional, small-scale farms (MacDonald *et al*., 2007). Changing production conditions, especially the selection of high-yielding dairy breeds during the past decades (Autonome Provinz Bozen-Südtirol, 2017) may already indicate that farmers try to compensate their high expenses with an intensification of milk production. Intensification in dairy systems is complex and mainly associated with higher milk yields, as well as changes in farm size and stocking density (Clay *et al*., 2020). However, in mountain areas, the opportunity to change farm size and stocking density are very limited and thus increasing the total amount of milk production per cow and farm is usually only possible by using higher-yielding breeds or increasing concentrate levels.

Some authors already reported an impact of concentrate supplementation on health and welfare. The prevalence and severity of lameness was higher in dairy cows fed with high compared with low amounts of concentrate (11 *v.* 7 kg/cow/d: Manson and Leaver, 1988).

Other studies did not find an impact on fertility traits (Horan *et al.*, 2004; Delaby *et al.*, 2009; Horn *et al.*, 2014). Spiekers *et al.* (1991) also did not observe an effect regarding the number of veterinary treatments, reproductive performance or culling. A further study (Leiber *et al.*, 2017) monitored different groups of organic dairy farms, which reduced the amount of concentrate to a certain level (between 0 and 1.14 kg concentrate/cow/d), over a six-year period. Although milk yield decreased during the experiment in all groups that reduced the amount of concentrate fed, this was not significant. Furthermore, milk protein, somatic cell count, fat protein ratio, average number of lactations, calving intervals and frequency of veterinarian treatments did not differ by group and year (Leiber *et al.*, 2017). However, the use of large amounts of concentrates can have a negative impact on animal welfare, especially due to the associated intensification of milk production (Koeck *et al.*, 2014). At the same time, it can be problematic to meet the energy requirements of high-yielding animals when feeding a grass-based diet (Charlton *et al.*, 2011).

To our knowledge, the combination of the level of concentrate feed and the used breed is rarely considered when studying the welfare of dairy cows. Therefore, the objective of this study was to investigate the influence of high *v.* low concentrate feeding as well as the influence of breed (lower yielding Tyrolean Grey *v.* higher yielding Brown Swiss) and their interactions on animal- and resource-based welfare indicators as well as health and reproduction parameters.

## Materials and methods

### Study area and farms

The study region South Tyrol, with a total area of 7400.43 km$^2$, is situated in the very northern part of Italy. The province is dominated by a continental climate and, because of its inner-alpine location, little precipitation with on average 667 mm yearly in the capital Bolzano. However, the climatic conditions widely vary between valley and mountainous areas (Adler, 2015). Only 14% of its land area is below an altitude of 1000 m above sea level (a.s.l.), 49% between 1000 and 2000 m a.s.l. and 37% above 2000 m a.s.l. (Autonome Provinz Bozen-Südtirol, 2017).

In this study, 64 small-scale dairy farms were included. These farms were selected through the Dairy Association of South Tyrol and breeder's associations. The selection criteria was a farm location above 700 m a.s.l and a herd size of 7–20 dairy cows of either the breed Tyrolean Grey (TG) or Brown Swiss (BS). The participation of the farms was voluntary.

Selected farms were classified based on the amount of concentrates fed and breed of cow into four groups: L-TG, ≤3.5 kg concentrate/day/cow Tyrolean Grey; L-BS: ≤4.5 kg concentrate/day/cow Brown Swiss; H-TG, ≥6.0 kg concentrate/day/cow and H-BS, 7.5 kg concentrate/fodder/day/cow. All farms used a dairy concentrate with contents of crude protein between 16 and 21%. In addition all cows received hay ad libitum.

### Data collection

Data for resource and animal-based measurements were collected during farm visits, which took place during the winter housing period from October to May. The Welfare Quality Protocol is mainly addressed to large and intensive farms with loose housing barns (Welfare Quality®, 2009) thus, it was adjusted with recommendations by the European Food Safety Authority (EFSA). This protocol is provided for small-scale dairy farms characterized by local or dual-purpose breeds, less than 75 lactating dairy cows and family farms (EFSA, 2015), which was the case for all farms represented in this study.

Each farm was visited once by two assessors. One of them assessed the animal and resource-based measures and the second interviewed the farmer to collect data on management measures. Animal and resource-based measures were assessed in the barn by one observer using the combined protocol from Welfare Quality® and EFSA recommendations. During the interview, the farmer was asked to complete a questionnaire including questions about management practices (days on pasture, amount and type of concentrate supplementation) and business (full- or part-time, direct marketing or cooperatives, number of employees). Most of the questions were closed with a defined selection of response options. However, the questions about farm structures such as the size of farm areas, length of grazing period, the amount of the different feed components, and the type of concentrate feed were open to allow exact answers.

### Assessment of animal-based measures

A total of 798 cows on 64 farms were assessed between October 2017 and May 2018 with each farm being visited once for this assessment and all cows being assessed whilst in the barn. On-farm assessment on one farm took between 3 and 4 h. An overview of the animal-based measures and the assessment method is given in online Supplementary Table S1.

### Assessment of health and reproductive performance

Further information was gathered using the milk data from test day records for a three-year period from October 2014 to October 2017 and data from artificial insemination. Detailed information about the health and reproductive classifications and evaluations at farm level can be found in online Supplementary Table S2.

### Assessment of resource-based measures

Resource-based measures were assessed between October 2017 and May 2018 during farm visits. Resource-based measures comprised type of husbandry system, number of water points, cleanliness and function of water points, dimensions of the lying area, cleanliness of the lying area, air quality and the presence of electric cow trainers (online Supplementary Table S3). Electric cow trainers typically consist of a metal rod placed a few centimeters above the cow's back. When a cow arches her back to defecate while standing in the front of the barn, she comes into contact with the electric cow trainer and receives an electric shock. This is to teach the animals to step backward before urinating and defecating to avoid such shocks and thus keep the stalls clean (Oltenacu *et al.*, 1998). The use of electric cow trainers is limited to tie stalls.

In addition, hay samples from the first cut were collected on the farm. A bulk sample of approximately 4 kg was mixed on

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every farm, by collecting five individual samples. Proximate analysis was done according to Kirchgeßner (2008). The amount of milk produced from roughage was calculated by using the formula (Weiß, 2001):

$$\left(\frac{7\ \text{MJ NEL}}{\text{kg concentrate}} \times \frac{\text{concentrate in tons}}{\text{cow and year}} \times 100\right) - \left(\frac{(7\ \text{MJ NEL/kg concentrate}) \times (\text{concentrate in tons /cow and year})}{3.2}\right) \times 100$$

### Statistical analysis

Using SAS 9.4 (Statistical Analysis Systems, Cary, North Carolina, USA), the Kolmogorov-Smirnov test for normal distribution was applied, with values lower than 0.05 indicating abnormal distribution. For some of the variables, the log transformation was required to ensure homogeneity of variance. The fixed effects of either level of intensification (low- *v.* high-input) and breed (BS *v.* TG), as well as the interaction between the level of intensification and the breed were tested for animal and resource-based measures, and also for health and reproductive performance measures by applying the procedure PROC MIXED. The model used was;

$$Y_{ijk} = \mu + a_i + b_j + a_i{*}b_j + f_k + e_{ijk}$$

where $Y_{ijk}$ is the dependent variable (welfare indicator), μ is the overall mean, $a_i$ is the fixed effect of the intensity level $i$ ($i$ = low-input; high-input), $b_j$ is the fixed effect of the breed $j$ ( $j$ = Tyrolean Grey; Brown Swiss), $a_i{*}b_j$ is the fixed effect of the interaction between intensity level and breed, $f_k$ is the random effect of the farm $k$ ($k$ = 1; 2; 3;….; 64) and $e_{ijk}$ is the random error term. Effect of year for health and reproductive performance indicators was excluded from the final model, as it showed no significant influence. Data are expressed as means with standard deviation.

The overall significance was tested with an F-Test. When an overall significant effect of the assessment was detected, post hoc pairwise comparisons for the groups (L-TG, L-BS, H-TG, H-BS) were performed using the Bonferroni test. Frequency distributions were compared by Fisher's exact test. Significance was accepted for $P$ values <0.05. Measures with zero prevalence were excluded. For the calculation of correlations between variables, the procedure proc corr was performed using the Pearson correlation test.

## Results

### Farm characteristics

Farm data are given in Table 1. All farms were managed as family businesses and sold their milk through cooperatives, and all were located at 1000-meter above sea level or greater. Except for the group L-BS, the majority of farmers worked exclusively on their farms without external employment. In this study, energy corrected milk (ECM)/cow and year increased with increasing concentrate level. The predominant husbandry system was tie-stall for all groups, even though 42% of the H-BS farms had a loose housing system. Days of pasture decreased with an increasing concentrate level with L-TG being highest to H-BS being lowest.

### Animal based measures

Results for animal-based measures showing a significant difference are given in Table 2, and the full dataset is in online Supplementary File S4. For the prevalence of lean cows, significant differences were observed, with a higher prevalence in the group L-BS than in L-TG and H-TG. Both fixed effects, breed and intensity level showed a significance.

The percentage of cows with dirty flank and/or upper leg, dirty hind leg as well as dirty udder was significantly higher in L-BS than in H-TG and H-BS. For all three parameters, a significance for the effect of intensity level could be observed, as well as for the effect of breed regarding the parameter dirty hind leg. Additionally, correlations between dirty flank/upper leg and dirty hind leg ($P$ < 0.001, $r$ = 0.73), dirty flank/upper leg and dirty udder ($P$ < 0.001, $r$ = 0.78) and dirty hind leg and dirty udder ($P$ < 0.001, $r$ = 0.63) were found. In terms of hairless patches, a significant difference was found between the groups of L-BS and H-TG, with a higher prevalence of hairless patches in L-BS. Additionally, a significance for the effect of the breed was found, with a lower percentage of cows with hairless patches for TG.

No significant differences between groups were observed for the percentage of animals with lesions, open shoulder, ocular discharge, vulvar discharge, nasal discharge, hampered respiration, diarrhea, incorrect lying down behavior or lame animals (online Supplementary Table S4).

### Health and reproductive performance

Age at first calving was significantly lower in H-BS compared to all other groups (Table 3). Cows of the group L-BS had longer calving intervals compared to the other groups. The highest percentage of cows with a cell count ≥ 400 000 was found in the group L-BS, which differs significantly compared to H-TG. In both TG groups, the percentage of cows with a fat-protein-quotient <1 was significantly higher than in the BS groups. The number of lactations was found to be significantly higher in L-TG than in H-BS. Furthermore, there was a negative correlation between age of first calving and numbers of lactations ($P$ < 0.001, $r$ = −0.40). For dystocia, a significant effect of the intensity level was observed, with higher levels for both low-input compared to the high-input systems.

The full health and reproductive performance dataset is given in online Supplementary Table S5. No significant differences between groups could be observed for insemination index, lifetime production and animals with a milk urea >300 mg/l.

### Resource-based measures

These data are shown in Table 4. No significant differences between the groups were found for dirty water points, length and width of lying area, the presence of an electric cow trainer or the energy content of hay. For forage performance,

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**Table 1.** Farm characteristics of the 64 small-scale mountain dairy farms, divided into the groups L-TG, L-BS, H-TG and H-BS depending on breed and concentrate use

| Farm descriptor | L-TG | L-BS | H-TG | H-BS |
|---|---|---|---|---|
| *N* | 14 | 15 | 15 | 20 |
| Height[a] | 1141 ± 324 | 1266 ± 266 | 1294 ± 261 | 1120 ± 240 |
| Full-time (%) | 57 | 27 | 80 | 85 |
| Herd size (*n*) | 12.2 ± 4.3 | 10.1 ± 4.6 | 13.6 ± 5.6 | 14.8 ± 4.5 |
| Tie stall (%) | 84.6 | 91.7 | 92.7 | 58.8 |
| Pasture (ha) | 4.6 ± 4.9 | 6.4 ± 4.1 | 6.1 ± 6.1 | 0.14 ± 0.4 |
| Days of pasture | 97.1 ± 70.1 | 76.7 ± 47.7 | 52.1 ± 56.8 | 19.4 ± 29.2 |
| Concentrate/cow and day (kg) | 2.8 ± 0.8 | 4.0 ± 1.5 | 6.1 ± 1 | 8.7 ± 1.3 |
| ECM[b]/cow/year (kg) | 4220 ± 349 | 5179 ± 709 | 5748 ± 717 | 7675 ± 1071 |

Values are mean ± standard deviation. L is low concentrate allowance and H is high concentrate allowance, TG is Tyrolean Grey breed and BS is Brown Swiss breed.
[a]Meter above sea level.
[b]Energy corrected milk yield, adjusted to 3.5% fat and 3.2% protein.

**Table 2.** Animal based measures for the 64 small-scale mountain dairy farms, divided into the groups L-TG, L-BS, H-TG and H-BS depending on breed and concentrate use, restricted to parameters exhibiting significant differences

| | Mean ± SD | | | | *P*-value | | |
|---|---|---|---|---|---|---|---|
| | L-TG | L-BS | H-TG | H-BS | Breed | Intensity level IL | Breed × IL |
| *N* | 14 | 15 | 15 | 20 | | | |
| Lean cows[a] (%) | $9.5^{a}$ ± 7.1 | $28.3^{b}$ ± 12 | $13.2^{a}$ ± 7.2 | $15.1^{ab}$ ± 8.3 | <0.001 | <0.001 | <0.001 |
| Dirty flank and/or upper leg (%) | $34.5^{ab}$ ± 30.2 | $49^{a}$ ± 28.5 | $12.8^{b}$ ± 12.3 | $19.6^{b}$ ± 19.2 | n.s. | <0.001 | n.s. |
| Dirty hind leg (%) | $26.8^{a}$ ± 27.6 | $53.7^{b}$ ± 36.4 | $20.2^{a}$ ± 24.7 | $20.3^{a}$ ± 28 | 0.04 | <0.001 | 0.04 |
| Dirty udder (%) | $27.5^{ab}$ ± 26.6 | $36.1^{a}$ ± 26.6 | $11.7^{b}$ ± 19.5 | $21.9^{ab}$ ± 22.4 | n.s. | 0.02 | n.s. |
| Hairless patches (%) | $2.5^{ab}$ ± 4.2 | $10.8^{a}$ ± 17.9 | $0.9^{b}$ ± 2.4 | $4.2^{ab}$ ± 6.5 | 0.03 | n.s. | <0.001. |

Values are mean ± standard deviation. L is low concentrate allowance and H is high concentrate allowance, TG is Tyrolean Grey breed and BS is Brown Swiss breed.
[a]Cows with a BCS ≤2 were considered as too lean. Within a row, values that do not share a common superscript differ at $P < 0.05$.

significantly higher amounts were observed for both low-input systems (48.6 and 43.3% for L-TG and L-BS, respectively) compared to high-input systems (26.9 and 29.8% for H-TG and H-BS, respectively).

## Discussion

### *Farm characteristics*

The comparison of the four farm groups showed that the groups differ for some management issues. The extensive farms were more frequently managed part-time and loose housing systems were found predominantly on farms using the high yielding breed BS and feeding higher amounts of concentrate. This is in line with results by Mattiello *et al.* (2009) who also state that tie-stalls are most common in alpine areas. Furthermore, the duration that cows were kept on pasture was lower for BS farms and those feeding higher amounts of concentrate. According to Zendri *et al.* (2016), local breeds such as TG are more appropriate for alpine pastures and need less energy compared to high yielding breeds, which might be the reason why TG farms had a higher number of days on pasture. These differences are important confounding factors for the results regarding the cow's welfare, health and reproductive performance. Existing studies already reveal that the husbandry system (Regula *et al.*, 2004), as well as the number of days on pasture (Corazzin *et al.*, 2010), influence animal welfare and health issues.

### *Animal-based measures*

The percentage of cows considered as too lean was higher than recorded in another study that focused mainly on a comparison of animal welfare parameters between tie-stalls (2.24%) and loose-housing (5.07%) (Ostojić-Andrić *et al.*, 2011). Mattiello *et al.* (2009) shows very similar results to ours with 13.7% of lactating cows being classified as too lean. The high percentage of cows considered as too lean in the group L-BS might be due to the fact that the high yielding breed BS is not compatible with an extensive feeding system. This might also explain the significant results for both effects, breed and intensity level within the group comparison. Zollitsch *et al.* (2016) states that high-yielding dairy cows have been selected under high-concentrate input conditions, while dual-purpose breeds, like TG, are more adapted to the harsh environment of mountain areas. Thus, for individual animals in the group L-BS freedom from hunger cannot be ensured.

For the cleanliness of animals, other studies already found explanatory variables: one of the most important among bedding material and husbandry techniques is the stall dimension (Chaplin *et al.*, 2000; Cook, 2002; Hauge *et al.*, 2012). The fact that the length

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**Table 3.** Health and reproductive parameters for the 64 small-scale mountain dairy farms, divided into the groups L-TG, L-BS, H-TG and H-BS depending on breed and concentrate use, restricted to parameters exhibiting significant differences

| | Mean ± SD | | | | *P*-value | | |
|---|---|---|---|---|---|---|---|
| | L-TG | L-BS | H-TG | H-BS | Breed | Intensity level | Breed × Intensity level |
| *N* | 14 | 15 | 15 | 20 | | | |
| Age at first calving (months) | $33.5^{a} \pm 1.9$ | $32.9^{a} \pm 2.9$ | $33.3^{a} \pm 1.6$ | $30.8^{b} \pm 1.8$ | <0.01 | 0.04 | n.s. |
| Calving interval (days) | $411.9^{a} \pm 30.6$ | $489.7^{b} \pm 78.7$ | $421.4^{a} \pm 37.1$ | $436.1^{a} \pm 33.6$ | <0.01 | n.s. | 0.02 |
| Cell count ≥400 000 (%) | $6.7^{ab} \pm 11.3$ | $12.7^{a} \pm 6.9$ | $4.4^{b} \pm 12.8$ | $9.2^{ab} \pm 9.3$ | 0.04 | n.s. | n.s. |
| Fat to protein ratio <1 (%) | $21.3^{ab} \pm 11.3$ | $10.7^{a} \pm 6.9$ | $22^{b} \pm 12.8$ | $17.4^{ab} \pm 9.3$ | 0.02 | n.s. | n.s. |
| Dystocia (%) | $20.5^{a} \pm 10.1$ | $20.3^{a} \pm 18.9$ | $12.1^{a} \pm 6.3$ | $17.3^{a} \pm 8.2$ | n.s. | 0.02 | n.s. |
| Lactations (no.) | $3.6^{a} \pm 0.5$ | $3.2^{ab} \pm 0.6$ | $3.1^{ab} \pm 0.5$ | $2.4^{b} \pm 0.4$ | 0.03 | <0.01 | n.s. |

Within a row, values that do not share a common superscript differ at $P < 0.05$.

**Table 4.** Resource based measures for the 64 small-scale mountain dairy farms, divided into the groups L-TG, L-BS, H-TG and H-BS depending on breed and concentrate use

| Mean ± SD | | | | | *P*-value | | |
|---|---|---|---|---|---|---|---|
| Resource based measures | L-TG | L-BS | H-TG | H-BS | Breed | Intensity level | Breed × Intensity level |
| *n* | 14 | 15 | 15 | 20 | | | |
| Dirty water points (%) | $37.5^{a} \pm 27.3$ | $39.3^{a} \pm 16.4$ | $19.1^{a} \pm 12.9$ | $37.5^{a} \pm 19.8$ | n.s. | n.s. | n.s. |
| Length of lying area (cm) | $188.2^{a} \pm 20.8$ | $190.6^{a} \pm 37.3$ | $181.1^{a} \pm 21.1$ | $175.3^{a} \pm 14.6$ | n.s. | n.s. | n.s. |
| Width of lying area (cm) | $106.1^{a} \pm 10.2$ | $107.3^{a} \pm 8.9$ | $102.1^{a} \pm 15.6$ | $105.8^{a} \pm 12.3$ | n.s. | n.s. | n.s. |
| Presence of an electric cow trainer (%) | $50.0^{a}$ | $33.3^{a}$ | $66.7^{a}$ | $35.0^{a}$ | | n.s.[a] | |
| Energy content of hay (MJ/kg DM) | $5.01^{a} \pm 0.4$ | $5.2^{a} \pm 0.5$ | $5.2^{a} \pm 0.2$ | $5.1^{a} \pm 0.2$ | n.s. | n.s. | n.s. |
| Milk out of roughage (%) | $48.6^{a} \pm 1\ 3.4$ | $43.3^{a} \pm 20.2$ | $26.9^{b} \pm 13.0$ | $29.8^{b} \pm 10.6$ | n.s. | <0.01 | n.s. |

Values are mean ± standard deviation. L is low concentrate allowance and H is high concentrate allowance, TG is Tyrolean Grey breed and BS is Brown Swiss breed.
[a]Fisher's exact test.
Within a row, values that do not share a common superscript differ at $P < 0.05$.

of the lying area is decisive for the cleanliness of cows indicates that stalls should be appropriate for the breed, which might be problematic for the breed BS in old tie-stalls and thus explain the high numbers of animals classified as dirty in this study.

Regarding the percentage of animals with hairless patches, Mattiello *et al.* (2011) reports a higher percentage than our findings for BS with 20.8% and a similar percentage to our findings for TG with 2.4%. However, we visited most of the farms during autumn when 60.3% of the farmers allow their dairy cows excess to pasture. A beneficial effect of pasture on reducing injuries due to the absence of constraining housing equipment and thus fewer collisions, is already reported by other studies (Corazzin *et al.*, 2010; Zuliani *et al.*, 2017). The higher percentage of animals with hairless patches in the group L-BS might be explained by their large frame leading to more collisions with housing equipment than in smaller breeds like TG, when kept in tie-stalls. This is in accordance with Mattiello *et al.* (2011) and Katzenberger *et al.* (2020) who report that local breeds showed lesser animal welfare problems than high producing dairy cows when kept in alpine tie-stalls. However, the keeping of dairy cows in tie-stalls is very restrictive and the freedom to express normal behavior is, regardless of the kept breed, strongly limited.

### Health and reproductive performance

Our finding that age at first calving is lowest in the H-BS group is in wide agreement with the finding that intensive farms with high-yielding breeds tend to have a lower age at first calving (Knaus, 2009). However, we found that the calving interval was highest for the group L-BS. The lower calving interval for TG is in agreement with the findings of Bieber *et al.* (2019) who report that local breeds have an up to 20 d shorter calving interval and a lower insemination index than high yielding breeds. it is almost inevitable that part-time farmers, who represented the majority in the L-BS group, would have spent less time in the stable and thus were more likely to miss the right time for artificial insemination which increases the calving interval. Another possible explanation is the fact that L-BS have the highest percentage of cows considered as too lean, which might indicate less energy and thus a poorer reproductive state of the herd, which is in accordance with several other studies (Pryce *et al.*, 2002; Roche *et al.*, 2007).

The finding of increased numbers of high cell count cows in group L-BS correlates with the measures of dirty flank/upper leg, dirty hind leg and dirty udder which were also highest in this

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group. Several studies already report a high correlation between the cleanliness of cows and somatic cell count (Ward *et al.*, 2002; Ellis *et al.*, 2007; Sant'Anna and da Costa, 2011).

We found a higher percentage of cows with a fat:protein ratio (FPR) <1 for group TG. This should be interpreted with caution as typical values for this breed are around 3.76% fat and 3.39% protein in milk (Südtiroler Rinderzuchtverband, 2017). This, of course, leads to a smaller FPR compared to BS cows that have a fat content of around 4.15% and a protein content of around 3.56% (Brown Swiss breeding association of South Tyrol, 2017). However, there is no data available on the association between clinical acidosis and an FPR <1 in local breeds, therefore, it remains unclear if an FPR <1 is a valid indicator for risk of acidosis in TG. Another difference we found between the groups was the frequency of dystocia with a significant effect for the intensity level. An explanation might be that extensive farmers tended to use semen from other breeds (mostly Blue Belgian) more often in order to sell calves for meat production (36% *v.* 20%). Crossbreeding with beef breeds is known to be associated with increased risks of dystocia (Mee, 1990; Fourichon *et al.*, 2001).

In this study a longer productive livespan was found for the breed TG when compared to BS. This is in accordance with the findings of Bieber *et al.* (2019) and indicates that an increase in lactation performance is accompanied by a decreasing tendency of longevity, which was already stated by Essl (1982). These results might be partly explained by antagonistic genetic correlations between high yield and productive life (Pritchard *et al.*, 2013). However, this effect might be confounded with the intensity level of the system, as reported by Leiber *et al.* (2017). Longevity is an important trait for low-input systems as a shorter productive life span means that rearing investments have to be paid off in a shorter period of time (Bergeå *et al.*, 2016). Furthermore, Horn *et al.* (2014) found in organic dairy systems in Austria that cows reached their maximum annual milk yield in their fifth lactation.

### Resource-based measures

The fact that no differences between groups were found for length and width of lying area implies that tie-stall dimension is not adapted to keep tall framed dairy cows like BS. Mattiello *et al.* (2011) found a mean stall length of 175 cm but significant differences in stall width with 113 cm for BS and 121 cm for TG. Further, they concluded that dairy cow's breed significantly affects welfare in tie-stalls (with high-yielding breeds showing poorer welfare than dual-purpose breeds) and this might in part be due to stall dimensions. Across all groups the presence of an electric cow trainer was common, although the negative effects of the use of an electric cow trainer are well known. These include risk of silent heat, clinical mastitis and culling (Oltenacu *et al.*, 1998). While Zurbrigg *et al.* (2005) states that the presence of an electric cow trainer is associated with more animals considered as dirty, Bergsten and Pettersson (1992) report that cows housed in tie-stalls with electric cow trainers are cleaner. In line with the latter, in this study the group of H-TG had the most electric cow trainers and the least animals considered as dirty.

Further findings were that the collected hay samples showed low values for first-cut energy content (5.2 MJ/kg DM compared to >6.0 MJ/kg DM proposed by Resch *et al.*, 2010). This might be a problem during lactation especially for high-yielding breeds. Poetsch (2007) recommends that low input systems have to improve their forage quality, if external resources like concentrates should be reduced. This was not, however, the case in this study, as no significant differences for the net energy could be observed between intensity levels. In addition, forage performance was higher for extensive farms but lower than it is recommended. In extensive systems, 80% of milk yield should be derived from forage feeding and in intensive feeding at least 50% (Kiefer *et al.*, 2015).

The hypothesis that a high *v.* low concentrate supplementation has different effects on two dairy cow breeds in terms of animal welfare, health and reproductive performance can be confirmed for some indicators. Thus, BS cows showed poorer animal welfare, health and reproductive performance for some of the assessed indicators when fed with low amounts compared with BS cows fed with high amounts of concentrated feed. For TG no differences between the intensity levels could be observed. Since confounding factors (husbandry system, management practices) cannot be ruled out, further investigations are necessary.

### Limitations of the study

The objective of this study was to assess cow welfare in low and high-input systems depending on the breed. However, the comparison between the groups shows some weaknesses due to the uneven distribution of some important management factors that might have an influence on animal welfare. In addition, only one observer measured the animal-based indicators on the farm. For some parameters, it is suspected that some resource-based variables other than the breed and feed-intake are more important. However, the results from the group comparison show that most of the animal-based measures indicate poorer animal welfare for the group L-BS and better animal welfare for the group H-TG. This suggests that high-yielding breeds might not fit into an extensive mountain system. Nevertheless, these results should be interpreted with caution because of the confounding factors just mentioned. Other studies also indicate that management practices and housing conditions have a decisive influence on animal welfare (Gieseke *et al.*, 2018). Nevertheless, our results show that the breed should be adapted to the feeding and housing system, otherwise animal welfare might be compromised.

In conclusion, the results of the group comparison show that intensification through a higher concentrate level in diets does not lead to lower animal welfare for dairy cows in alpine regions. Rather, keeping high-yielding breeds in extensive systems seems to be challenging. This might not only be due to reduced labor effort in low input systems, but also because of the below average roughage quality in alpine regions, which makes it difficult to meet the energy requirements of high-yielding cows with a low concentrate supplementation. The dual-purpose breed TG showed some clear advantages in that calving interval was lower and the number of lactations greater.

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