Effects of cattle breed and production system on veterinary diagnoses and administrated veterinary medicine in alpine dairy farms

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ABSTRACT
The aim of the following study was to investigate the effect of dairy production systems, including housing, farm management, pasture access and concentrate supplementation on veterinary diagnosed diseases as well as on administrated drugs in local dual-purpose Alpine Grey (AG) cattle and specialised Brown Swiss (BS) cattle in alpine dairy systems. In the final dataset 916 veterinary diagnosis from 524 cows farmed in 6 low-concentrate Alpine Grey farms (LAG), 9 low-concentrate Brown Swiss farms, (LBS) 11 high-concentrate Alpine Grey farms (HAG) and 15 high-concentrate Brown Swiss farms (HBS) were available for the statistical analysis. The most diagnoses referred to udder health (mastitis, dry-cow therapy) followed by parasite infections and reproduction disorders. In detail, BS had a higher occurrence for mammary infections than AG while HBS farms showed a significant higher incidence for udder diseases compared to all other farm categories. Pasture access had in tendency a beneficial effect on udder health but was detrimental for cows fertility. For latter, special attention should be put on providing sufficient energy supply to grazing animals for avoiding severe negative energy balances and resulting metabolic disorders which reduce fertility. Finally, to reduce the use of antimicrobials classified as highly critical by the WHO in terms of resistance, selective therapies, particularly for mammary infections and dry-cow therapies as well as the inclusion of preventive strategies in every days farm management should be encouraged.

HIGHLIGHTS
- Pasture access has a favourable effect on udder health
- Selective veterinary treatments for udder infections and dry-off practice should be promoted
- Brown Swiss cows are more susceptible to mammary infections than Alpine Grey cows

Introduction
Animal health and welfare are crucial for the economic success of a farm (Pfeiffer et al. 2015). In fact, health and fertility disorders were stated to have a negative effect on longevity and reproductive ability of dairy cows and create next to veterinary treatment costs a series of follow-up costs caused by premature culling and higher restocking rates, reduced milk production and prolonged calving intervals (Helkälä et al. 2012; Kofler 2012; Martin et al. 2018; Mostert et al. 2018). Alpine dairy farms are very different production systems in sense of size, husbandry and feeding systems and overall productivity as those present in the lowland areas of Europe and North America (Firth et al. 2019). Consequently, production costs per unit of output are higher and remuneration per working hour is lower (Pouloupolou et al. 2018; Kühl et al. 2020). Thus, a cost-effective production is of high importance in order to maintain farm profitability in such area. Next to feeding costs veterinary treatment costs were shown to have a relevant impact on total variable costs of alpine farms (Kühl et al. 2020). Accordingly, it is of farmers’ and other stakeholders’ interest to improve animal health and welfare in order to reduce veterinary costs as well as meet the increasing consumers’ demand for animal welfare and food safety (Egger-Danner et al. 2015). Latter is of high importance because of the rising concern of antimicrobial resistances (AMR) due to the overuse of partly poor-quality veterinary medicine for therapeutic use in livestock production systems (Clifford et al. 2018).
In Italy the registration of veterinary treatments in form of an electronic registration has become mandatory by law in 2019 (Law of the 20th November 2017 Nr 167 Art 3). Thereby, veterinarians have to register the prescribed drug and the general group of the observed diagnosis according to a specific diagnose key in the electronic recording system, which was established and is managed by the Italian Ministry of Health. Latter should enable the traceability of veterinary medicinal products and medicated feed and therefore promote a more diligent application of antimicrobial substances in livestock production. However, the electronic recording system provides only information about aplicated drugs but does not display information neither regarding farm system nor about farm management, which are known to have relevant impact on animal health and welfare (Ivemeyer et al. 2012; Åkerfeldt et al. 2021).

Therefore, information regarding veterinary diagnoses and administrated drugs in combination with data on management practice are required to gain better insights for preventing diseases and consequently reduce the use of veterinary medicine and the associated risk for AMR (Landers et al. 2012; Bengtsson and Greko 2014; De Monte et al. 2020). The objective of the following study was to investigate the effect of housing systems, farm management, pasture access and concentrate supplementation on veterinary diagnoses as well as on administrated drugs in local dual-purpose Alpine Grey (AG) cattle or specialised Brown Swiss (BS) cattle, both frequently farmed in low-input and high-input alpine dairy systems (Kühl et al. 2020) of South Tyrol (Sennereiverband 2019). Possible trial farms had to keep either local dual-purpose Alpine Grey cattle or specialised Brown Swiss cattle, feed either high or low amounts of concentrates in the feed ratio, possibly using pasture during the vegetation period, keeping the cows in either tie-stall or free-stalls, to be organised on a part-time (commonly practiced in alpine dairy production systems of South Tyrol) or full-time basis. The participation was on a voluntary basis. In order to consider the heterogenous degrees of production intensity in alpine dairy-production systems (Kühl et al. 2020) farms with different production intensity level in terms of concentrate use in the feed ration were considered and classified as follows (Kühl et al. 2020): 1) low-input AG (LAG) ≤ 3.5 kg concentrates/day and cow; 2) low-input BS (LBS) ≤ 4.5 kg concentrates/day and cow; 3) high-input AG (HAG) ≥ 6.0 kg concentrates/day and cow; 4) high-input BS (HBS) ≥ 7.5 kg concentrates/day and cow.

Crude protein in concentrate fodder varied between 16% and 21%. Following the classification criteria according to Kühl et al. (2020) 41 focus farms remained for the final investigation.

Direct health data per single animal regardless of sex and age were collected during farm visits considering the farm drug registry of respective farms. The observation period ranged from October 2014 to October 2017. Each event of the same disease was considered a new case on the same animal if it occurred at least one week after the previous event (Pérez-Cabal and Charfeddine 2013). For the evaluation of the drugs administrations the names of active substances of respective medical were considered. The active substances were identified individually by searching for the commercial name of each drug administered in the Dictionary of Veterinary Medicines and Animal Health Products XII edition 2017. Data were evaluated on the base of the classification of the critically important antimicrobials list of the World Health Organisation (WHO – CIA List; WHO 2019). Also, both painkiller and anti-inflammatory drugs were evaluated based on the active substance (e.g. NSAIDs, glucocorticoids). With regard to the drugs used on the various farms, it was decided to only describe the

Material and methods

Study area

The province of South Tyrol is located in the North-Eastern part of Italy on the border to Austria and Switzerland. Livestock production is characterised by small-scale farms, mostly run on a family basis. Approximately 72,000 hectares of field are used for feed production and 128,000 cattle are kept in the region of which 52% are dairy cows (Agrar- und Forstbericht 2019). The average South Tyrolean dairy farm is keeping 15 dairy cows and produces approximately 88,500 kg milk per year (Tätigkeitsbericht Sennereiverband 2019).
frequency of the active ingredients administered, as data on the dose administered per treatment were not available for all farms. According to the European Medicines Agency (EMA 2015, 2018), in order to assess quantitatively the antibiotic use, it is necessary to have data available on the daily amount administered per animal and the duration of treatment, in addition to the concentration of the antimicrobial contained in that particular commercial formulation and live weight of the animals (Defined daily dose - DDDv et and Defined Course dose - DCDvet).

After editing, a total of 916 diagnosis from 524 cows farmed in 6 LAG, 9 LBS, 11 HAG and 15 HBS farms were available for the statistical analysis.

**Statistical analysis**

Statistical analysis was performed with SAS software v. 9.4 (SAS Institute Inc., Cary, NC). Incidence of a diagnosis was defined as the proportion (%) of new cases of the disease on the total number of animals present in the barn over the studied period ((number of new cases/total animals at risk) × 100). Statistical analysis was only applied to veterinary diagnoses with an overall prevalence of 4% in the original dataset. Since the Kolmogorov-Smirnov and Shapiro-Wilks test for normality was significant (p < .05) for farm incidences and frequency of administrated substances, non-parametric test (Kruskal-Wallis) was applied. Significance level was set at p < .05. p-values were adjusted considering the Bonferroni correction method. Moreover, a multinomial logistic regression was performed, using the proc glimmix procedure to test potential risk factors associated with veterinary diagnosed diseases. The farm was included as a random effect for considering repeated health problems and related housing and management factors for multifactorial diseases. Each veterinary diagnosed disease was expressed as a binary variable (YES | NO) at the level of the individual dairy cow. Resource based measures and animal-based parameters depicted in Table 1 were classified as potential risk factors and were defined as binomial parameters. Descriptive statistics were performed to determine logical thresholds (Table 1). Farm was considered as random effect. For inclusion and exclusion of the potential risk factor a stepwise forward and backward selection was conducted. Only risk factors with a p-value < .05 were maintained in the final model. Odds ratios (OD) with 95% confidence intervals were calculated for every maintained risk factor in the final model. The goodness of fit of the models for respective diagnose was evaluated by drawing ROC curves and in determining the area under the curves (AUC). The AUC for the model describing udder diseases was 0.67 (SE:0.02; p < .001), for the model describing reproduction disorders 0.65 (SE:0.04; p < .001), for the model describing dry-off practice 0.67 (SE:0.02; p < .001), for the model describing parasite infections 0.89 (SE:0.01; p < .001) and for the model describing respiratory diseases 0.75 (SE:0.06; p < .001).

**Results**

**Farm characteristics**

Farm characteristics of the considered trial farms are depicted in Table 2. In terms of metres above sea, level HAG were the highest located farms (p < .05) whereas LBS were the lowest located farms (p < .05). Farms rearing AG cattle and farms feeding lower amounts of concentrates had significant longer pasture periods compared to high concentrate feeding farms and BS farms (Table 2). Further, LAG and HAG farms kept significant more animals (p < .05), in particular more calves and heifers, than HBS and LBS farms. The dominant husbandry system in all farms was tethering (70%), except for LAG, where free-stall and tethering systems were equally found (Figure 1). High concentrated feeding farms were mostly run on a full-time basis (>80%) whereas approximately one third of low concentrated feeding farms were run on a part-time basis (Figure 2).

**Veterinary diagnoses**

Number of diagnoses and respective frequency of diagnoses are illustrated in Table 3. A total of 916 veterinary diagnoses were recorded in the farms during the study period. The most frequent veterinary diagnoses concerned udder health management with mastitis and dry-off practice. Moreover, diagnoses regarding parasite infection played a relevant role (Table 3). In latter, nearly all referred to prophylactic and metaphylactic treatments against helminths, particularly. Regarding reproduction disorders retained placenta and metritis were the most frequent.

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**Table 1.** Classification of resource-based measures and animal-based parameters as potential risk factors.

| Parameters             | Classes                  |
|------------------------|--------------------------|
| Pasture access         | Yes | no                     |
| Pasture period         | >45 days | ≤45 days               |
| Farm dimension         | >12 cows | ≤12 cows               |
| Husbandry System       | Free-stall | Tie-stall            |
| Concentrates level     | High | low                    |
| Business organisation  | Full-time | part-time         |
| Breed                  | Brown Swiss | Alpine Grey         |
diagnoses (Table 3). Disbudding and digestive disorders presented a frequency of 4% and respiratory diseases 5% of which crowding disease was the most frequent veterinary diagnose. Veterinary diagnoses with an overall frequency of $\leq 4\%$ are summarised in Others and concerned locomotive apparatus, urinary apparatus, skin, metabolic status, nervous system and calve diseases (Table 3).

### Farm incidences

Mean farm values with respective standard deviations are depicted in Table 4. The incidence for udder diagnoses was significantly highest ($p < .05$) in HBS farms but was not significantly different between the other farm categories. Dry-off practice was not significantly ($p < .05$) different among farm categories. Similarly, no statistical difference was observed for diagnoses referring to parasite infections (Table 4). The incidence for reproduction diagnoses were higher in BS farms but not significantly different from farms rearing AG cattle. Incidences for respiratory diseases were not significant between farm systems. Finally, incidences for diagnoses concerning digestive apparatus and disbudding were not significantly different between respective farm categories (Table 4).

### Use of active substances

During the observation period 1732 drugs were administrated. Thereby antibiotics represented 78.52% of all treatments ($N = 1360$), followed by painkillers and anti-inflammatory active substances (NSAIDs, Table 2. Structural characteristics of investigated farms.

|               | HBS ($n = 15$) | HAG ($n = 11$) | LBS ($n = 9$) | LAG ($n = 6$) | Kruskal–Wallis** (df = 3) |
|---------------|----------------|----------------|---------------|---------------|---------------------------|
| Masl, m$^a$   | 1,134$^a$     | 1,294$^a$     | 1,028$^b$    | 1,160$^b$    | 188.800 < .001            |
| pasture days, d | 16$^a$       | 26$^a$       | 48$^a$       | 20$^a$       | 357.000 < .001            |
| cows, $n$     | 12$^b$        | 12$^c$       | 11$^d$       | 13$^a$       | 68.000 < .001             |
| calves, $n$   | 2$^d$         | 4$^b$        | 3$^b$        | 6$^a$        | 221.700 < .001            |
| heifers, $n$  | 4$^b$         | 6$^a$        | 4$^b$        | 7$^a$        | 135.700 < .001            |
| Total, animals, $n$ | 18$^a$     | 32$^b$       | 22$^b$       | 26$^a$       | 206.500 < .001            |

Different superscript letters within a row are significantly different ($p < .05$) for pairwise comparison of group means using the Wilcoxon rank-sum test; $^a$Metres above sea level; $^{**}$the Kruskal–Wallis test was used to test for differences among the 4 farm categories.

**Table 3.** Descriptive statistics of veterinary diagnoses.

| Veterinary diagnoses | Frequency | $n = 916$ |
|----------------------|-----------|-----------|
| Udder diseases       | 38%       | 352       |
| Mastitis             | 38%       | 346       |
| Others               | 1%        | 6         |
| Dry-off practice     | 21%       | 190       |
| parasites            | 11%       | 103       |
| Helmins              | 11%       | 102       |
| Coccidiosis          | 0%        | 1         |
| Reproduction disorders | 9%       | 86        |
| Retained placenta    | 6%        | 53        |
| Metritis             | 2%        | 15        |
| Others               | 2%        | 18        |
| Respiratory diseases | 5%        | 45        |
| Crowding disease     | 3%        | 29        |
| Pneumonia            | 2%        | 16        |
| Digestive disorders  | 4%        | 40        |
| Diarrhea             | 1%        | 12        |
| Others               | 4%        | 38        |
| Disbudding           | 4%        | 39        |
| Others               | 7%        | 61        |

Bold letters indicate Diagnose groups.

**Figure 1.** Frequency of husbandry systems in respective farm category (HBS: High-Input Brown Swiss farms; HAG: High-Input Alpine Grey farms; LBS: Low-Input Brown Swiss farms; LAG: Low-Input Alpine Grey farms).

**Figure 2.** Business organisation in respective farm category (HBS: High-Input Brown Swiss farms; HAG: High-Input Alpine Grey farms; LBS: Low-Input Brown Swiss farms; LAG: Low-Input Alpine Grey farms).
Table 4. Calculated farm diagnoses incidences for respective farm categories.

| Diagnoses group   | HBS       | HAG       | LBS       | LAG       | Kruskall–Wallis* (df = 3) |
|-------------------|-----------|-----------|-----------|-----------|---------------------------|
|                   | Mean      | Std       | Mean      | Std       | Mean                      | Std       | Mean                      | Std       | Chi² | p         |
| Udder, %          | 27.600    | 12.200    | 10.000    | 7.700     | 10.500        | 5.700     | 8.800                    | 7.900     | 18.900 | <.001     |
| Dry-off, %        | 10.400    | 19.300    | 3.400     | 10.000    | 5.600         | 5.200     | 17.100                   | 19.300    | 7.300  | .060      |
| Parasites, %      | 2.300     | 5.800     | 8.000     | 13.600    | 0.000         | 0.000     | 9.900                    | 18.300    | 3.600  | .310      |
| Reproductive app.,% | 4.600    | 6.800     | 3.400     | 3.200     | 4.300         | 3.000     | 2.400                    | 3.000     | 1.200  | .740      |
| Respiratory system,% | 3.400  | 7.300     | 0.700     | 1.300     | 2.800         | 5.900     | 0.200                    | 0.400     | 3.000  | .390      |
| Digestive app.,%  | 1.900     | 2.500     | 2.100     | 3.800     | 2.800         | 4.200     | 0.200                    | 0.600     | 4.400  | .220      |
| Disbudding, %     | 4.100     | 8.300     | 0.000     | 0.000     | 0.000         | 0.000     | 1.900                    | 4.300     | 5.000  | .170      |

Different superscript letters within a row are significantly different (p < .05) for pairwise comparison of group means using the Wilcoxon rank-sum test; *the Kruskal–Wallis test was used to test for differences among the 4 farm categories.

TAG: low-concentrate Alpine Grey farms; LBS: low-concentrate Brown Swiss farms; HAG: high-concentrate Alpine Grey farms; HBS: high-concentrate Brown Swiss farms.

glucocorticoids and analgesics; 7.85%; N = 136) and antiparasitic drugs (5.95%; N = 103). Hormones (1.56%; N = 27) and local anaesthesia (2.54%; N = 44) were less frequent. The most common antiparasitic drugs contained ivermectin (47.57%; N = 49), followed by the combination of ivermectin and clorsulon (40.77%; N = 42). Eprinomectin, which is normally used in lactating animals, was administrated in 11.7% of all treatments. Further, 18.5% of administrated antibiotics belonged to groups classified by the WHO as Highest Priority Critically Important Antimicrobials (N = 252), 31.6% belonged to groups classified by the WHO as High Priority Critically Important (N = 430) and the remaining 49.9% were antimicrobials classified as highly important (N = 678). In general, Highest Priority Critical Important antimicrobials seemed to be used more often in farms rearing BS (43.4%, Table 5). Moreover, 25.71% of the antimicrobials used for udder diseases belonged to the WHO High Priority Critical Important antimicrobials (N = 190), 16.33% to WHO High Priority Critical Important antimicrobials (N = 221) and 44.38% to Highly Important Antibiotics (N = 328). Highest Priority Critical Important antibiotics were used more carefully for dry-off and reproductive disorders (7.81% and 7.31%, respectively). For dry-off treatments WHO High Priority Critical Important antimicrobials and Highly Important Antibiotics were used at a similar percentage (46.90% and 45.27%, respectively). Finally, disorders affecting the reproductive apparatus were treated mainly with less significant antimicrobials in terms of AMR (67.47%).

Risk factor analysis

Resourced based measures and animal-based parameters influenced the risk for veterinary diseases diagnosed by veterinarians (Table 6). For the veterinary diagnoses referring to digestive apparatus and disbudding no significant risk factor was determined. The risk for udder diseases was higher (OR 2.795) in BS and in farms keeping more than 12 cows. In contrast, the occurrence of udder diseases was lower when cows had access to pasture or longer pasture periods and were fed with lower amounts of concentrates (Table 6). Further, reproduction disorders were more likely to occur when animals had access to pasture or had longer pasture periods. However, the risk for reproduction disorders was lower in farms organised on a full-time basis. Dry-off practice was more common in full-time farms keeping AG in tie-stalls and feeding low amounts of concentrates whereas farms using pasture and long pasture periods showed a lower occurrence for dry-off practice (Table 6). Furthermore, the risk for parasite infections was lower in BS and in big farms feeding low concentrate levels and keeping the animals in tie-stalls. Finally, respiratory diseases were more likely to occur in BS cattle (Table 6).

Discussion

To the best of our knowledge, this is the first study combining management data and veterinary diagnosed diseases with information about administrated drugs. The aim of the following study was to investigate the effects of cattle breed, housing system and farm management on veterinary diagnosed diseases and on the application of veterinary administrated medicals.

The high frequency of udder diseases observed in the following study (Table 3), of which the lions share is related to mastitis, is in line with results reported in literature (Egger-Danner et al. 2012; Ribeiro et al. 2013; De Monte et al. 2020). The significant higher incidence for udder diseases in HBS (Table 4) might be related to both, cattle breed and intensive farm management. In fact, it is well known that mastitis is a multifactorial disease (De Vliegher et al. 2018) for which environmental, management and animal related factors all play an important role. In our case the higher incidences for udder diseases observed in HBS might be
Table 5. Descriptive statistics of antimicrobials used in respective farm categories.

| WHO-class                     | HBS (n = 673) | HAG (n = 272) | LBS (n = 189) | LAG (n = 226) |
|-------------------------------|---------------|---------------|---------------|---------------|
|                               | n  | %  | n  | %  | n  | %  | n  | %  |
| Highest priority critically important | 157 | 23.3 | 38 | 14.0 | 38 | 20.1 | 19 | 8.4 |
| High priority critically important | 210 | 31.2 | 83 | 30.5 | 56 | 29.6 | 81 | 35.8 |
| Highly important              | 306 | 45.5 | 151 | 55.5 | 95 | 50.3 | 126 | 55.8 |

LAG: low-concentrate Alpine Grey farms; LBS: low-concentrate Brown Swiss farms; HAG: high-concentrate Alpine Grey farms; HBS: high-concentrate Brown Swiss farms.

Table 6. Risk factor analysis for veterinary diagnoses, considering cattle breed, concentrate feeding level, pasture access, pasture period, farm dimension, business organisation and husbandry system as risk factors.

| Risk factora | p-value | Level 1 | Level 2 | Odds ratiob | df | Confidence interval |
|--------------|---------|---------|---------|-------------|----|-------------------|
| Udder diseases |         |         |         |             |    |                   |
| Breed        | <.0001  | BS      | AG      | 2.7650      | 775| 1.9200–3.9800     |
| Level        | .0085   | Low     | High    | 0.5990      | 775| 0.4100–0.8800     |
| Pasture access | .0008   | Yes    | No      | 0.3460      | 775| 0.1900–0.6400     |
| Pasture period, days | .0202   | >45    | ≤45     | 0.4870      | 775| 0.2700–0.8900     |
| Farm dimension, n | <.0001  | >12 cows | ≤12 cows | 1.9930      | 775| 1.4200–2.8000     |
| Reproductive disorders |       |         |         |             |    |                   |
| Pasture access | <.0001  | Yes    | No      | 6.9320      | 777| 3.3700–14.2700    |
| Pasture period, days | <.0001  | >45    | ≤45     | 4.1140      | 777| 2.1500–7.8600     |
| Business organisation | .0001   | Full-time | Part-time | 0.3390     | 777| 0.2000–0.5900     |
| Dry-off practices |         |         |         |             |    |                   |
| Breed        | .0075   | BS      | AG      | 0.4870      | 772| 0.2900–0.8300     |
| Level        | <.0001  | Low     | High    | 3.8410      | 772| 2.2900–6.4500     |
| Husbandry system | .0091   | Free-stall | Tethering | 0.4070     | 772| 0.2100–0.8000     |
| Pasture access | .0026   | Yes    | No      | 0.1340      | 772| 0.0400–0.4900     |
| Pasture period, days | .0012   | >45    | ≤45     | 0.1190      | 772| 0.0300–0.4300     |
| Business organisation | <.0001  | Full-time | Part-time | 3.7540     | 772| 2.1600–6.3300     |
| Parasites infections |         |         |         |             |    |                   |
| Breed        | <.0001  | BS      | AG      | 0.0480      | 776| 0.0200–0.1000     |
| Level        | .0040   | Low     | High    | 0.4250      | 776| 0.2400–0.7600     |
| Husbandry system | .0130   | Free-stall | Tie-stall | 2.0930    | 776| 1.1700–3.7500     |
| Farm dimension, n | <.0001  | >12 cows | ≤12 cows | 0.0400     | 776| 0.0100–0.1700     |
| Respiratory diseases |       |         |         |             |    |                   |
| Breed        | .0204   | BS      | AG      | 3.6630      | 779| 1.2200–10.9700    |

aAll risk factors for the final model were significant (p < .05).
bOdds Ratio is given for the pairwise comparison between risk factor levels. Level 2 is the reference level. When Odds Ratio < 1 the risk is decreased in comparison with the reference level. When Odds Ratio > 1 the risk is increased in comparison with the reference level.

AG: Alpine Grey; BS: cattle and specialised Brown Swiss.

explained by unfavourable genetic association between udder health traits and milk yield traits (Heringstad et al. 2000; Koivula et al. 2005). Latter is further illustrated by the higher risk for udder disease in BS compared to AG observed in our study (Table 6). Moreover, pasture use and length of pasture period were shown to reduce the risk of mammary infections (Table 6) which is in line with results published in White et al. (2002), Fontaneli et al. (2005) and Firth et al. (2019), where pastured cows showed lower incidence of subclinical and clinical mastitis than confined cows. The lower risk associated with udder infections in pasture-based systems in our case might be related to better hygiene conditions on pasture compared to confined systems (Gösling et al. 2019). Further, an additional factor which might have favoured this outcome could be the fact that the prevalent housing systems in our trial were tie-stalls which were stated to have a higher incidence rate of clinical mastitis than free-stalls (Riekerink et al. 2008). The higher occurrence of reproductive disorders in farms with pasture access and longer pasture periods could be related to an insufficient energy supply in pasture fed cows compared to confined cows. Indeed in literature a lower BCS score was observed in pasture feeding systems compared to confined systems which might indicate a more severe negative energy balance resulting in a higher body fat mobilisation in pastured cows (Washburn et al. 2002; Hofstetter et al. 2014; Zendri et al. 2016). The resulting higher concentration of NEFA in blood was shown to negatively affect immune cell function and consequently increase the susceptibility for infectious diseases like metritis and subclinical endometritis (Ribeiro et al. 2013; Esposito et al. 2014). In addition, the risk for reproductive disorders was lower in full-time farms as farmers might have more time for animal control and observation than part-time farmers, who pursue additional employment.
outside the farm. Further, the higher occurrence of dry-off practice in low-input farms and AG cows could be related to a seasonal production pattern commonly used in pasture-based low-input systems. Finally, the risk for respiratory diseases was higher in BS than in AG which might be related to the higher adaptability of AG to local farming condition (Mattiello et al. 2011).

**Antibiotic administration**

In Austria, Firth et al. (2017), reported that antimicrobials were mainly administrated for treating udder diseases in 92% of the farms observed by which 79% used from WHO classified Highest Priority Critically Important antimicrobials (primary 3rd generation cephalosporin and cefoperazone) and High Priority Critically Important antimicrobials like beta-lactams. Similarly, Obritzhauser et al. (2016) described a wide use of Highest Priority Critically Important antimicrobials, corresponding to 24.6% of the total amount of antimicrobial administrated in Austria. In our study, the overall frequency of Highest Priority Critically Important antimicrobials applied was lower (18.52%), however, it should be noted that for udder diseases the use of Highest Priority Critically Important antimicrobials was with 14% of the total antimicrobials administrated in the present study relatively high. Therefore, in future treatments bacteriological test should be performed before actual treatment to identify the specific pathogen in order to formulate a respective treatment protocol which would enable a more targeted therapy. Latter could contribute to reducing the application of critical antimicrobial substances risky for causing resistance without minimising the success of the clinical outcome (Vasquez et al. 2017). Moreover, the use of selective dry cow therapy systems should be promoted (Cameron et al. 2015; Krömker and Leimbach 2017; Vanhoudt et al. 2018) as the use of antimicrobials for dry-off in our study was next to mastitis treatment the most common treatment-related to udder health management (Ferroni et al. 2020). In fact, according to the Italian guidelines on the use of antibiotics to contain the development of AMR bacteria that will be in force in 2022 (REGULATION (EU) 2019/6 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL), treatments should be carried out on the basis of a specific diagnosis and CIA Highest Priority Critically Important antimicrobials may only be administered on the basis of an antibiogram which indicates that type of active ingredient as first choice antimicrobials or in the absence of other effective active ingredients. Moreover, some very important antimicrobials necessary for treating human infection might no longer be allowed for veterinary use. For this reason, it can be assumed that in the next future the types and methods of antibiotic administration will vary considerably, as will the veterinarians work in the study area. Overall, regarding udder health, special attention should be put on preventive strategies like hygiene, milking management, milking technique, feeding of Vitamin E and Selen or genetic selection for resistance for reducing the application of antibiotics (Ruegg 2017). Finally, the frequency of antibiotics applied for reproduction disorders (9%) was similar to that reported in Ferroni et al. (2020).

**Conclusion**

In summary, the most common veterinary treatments in our study referred to the udder, where BS had a higher occurrence for mammary infections than AG and HBS farms showed a significantly higher incidence for udder disease compared to all other farm categories. Pasture access revealed to be favourable for udder health but problematic in terms of reproduction disorders as special attention should be put on providing sufficient energy supply to the grazing animals in order to avoid severe negative energy balances resulting in decreased fertility. Further, selective therapies for mammary infections and dry-cow therapies as well as the implementation of preventive strategies in respective farm management should be promoted to reduce the risk for AMR.

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**Ethical approval**

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

**Author contributions**

TZ analysed the data, drafted the manuscript, prepared the final report; EDM collected the field data; analysed the drug data and general diagnoses incidences, assisted in drafting the manuscript; MG designed the project, supervised all the data collection and data analysis. All authors read and approved the final manuscript.
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Data availability statement

The data that support the findings of this study are available on request from the corresponding author, Dr. Thomas Zanon. The data are not publicly available due to privacy.

References

Agrar- und Forstbericht. 2019. [accessed 2021 Feb 23]. http://www.provinz.bz.it/land-forstwirtschaft/landwirtschaft/agrar-forstbericht.asp

Åkerfeldt MP, Gunnarsson S, Bernes G, Blanco-Penedo I. 2021. Health and welfare in organic livestock production systems—a systematic mapping of current knowledge. Ogr Agr. 11(1):105–132.

Bengtsson B, Greko C. 2014. Antibiotic resistance-consequences for animal health, welfare, and food production Ups. Ups J Med Sci. 119(2):96–102.

Cameron M, Keefe GP, Roy JP, Stryhn H, Dohoo IR, McKenna SL. 2015. Evaluation of selective dry cow treatment following on-farm culture: milk yield and somatic cell count in the subsequent lactation. J. Dairy Sci. 98(4):2427–2436.

Clifford K, Desai D, Prazeres da Costa C, Meyer H, Klohe K, Winkler AS, Rahman T, Islam T, Zaman MH. 2018. Antimicrobial resistance in livestock and poor quality veterinary medicines. Bull World Health Organ. 96(9):662–664.

De Monte E, Zanon T, Vevey M, Gauly M. 2020. Evaluation of the systematic recording of diagnostic data in the Valdostana cattle. Ital J Anim Sci. 19(1):1255–1265.

De Vliegher S, Ohnstad I, Piepers S. 2018. Management and prevention of mastitis: a multifactorial approach with a focus on milking, bedding and data-management. J Integr Agric. 17(6):1214–1233.

Dictionary of Veterinary Medicines and Animal Health Products XII edition. 2017. Point Vétérinaire Italie srl, Milan.

Egger-Danner C, Cole JB, Pryce JE, Gengler N, Heringstad B, Bradley A, Stock KF. 2015. Invited review: overview of new traits and phenotyping strategies in dairy cattle with a focus on functional traits. Animal. 9(2):191–207.

Egger-Danner C, Fuerst-Waltl B, Obritzhauser W, Fuerst C, Schwarzenbacher H, Grassauer B, Mayerhofer M, Koeck A. 2012. Recording of direct health traits in Austria-experience report with emphasis on aspects of availability for breeding purposes. J Dairy Sci. 95(5):2765–2777.

EMA. 2015. Principles on assignment of defined daily dose for animals (DDDvet) and defined course dose for animals (DCDvet).

EMA. 2018. Guidance on collection and provision of national data on antimicrobial use by animal species/categories.

Esposito G, Irons PC, Webb EC, Chapwanya A. 2014. Interactions between negative energy balance, metabolic diseases, uterine health and immune response in transition dairy cows. Anim Reprod Sci. 144(3–4):60–71.

Ferroni L, Lovito C, Scoccia E, Dalmonte G, Sargenti M, Pezzotti G, Maresca C, Forte C, Magistrali CF. 2020. Antibiotic consumption on dairy and beef cattle farms of central Italy based on paper registers. Antibiotics. 9(5):273.

Firth CL, Käsbohrer A, Schleicher C, Fuchs K, Egger-Danner C, Mayerhofer M, Schobesberger H, Köfer J, Obritzhauser W. 2017. Antimicrobial consumption on Austrian dairy farms: an observational study of udder disease treatments based on veterinary medication records. PeerJ. 5:e4072.

Firth CL, Laubichler C, Schleicher C, Fuchs K, Käsbohrer A, Egger-Danner C, Köfer J, Obritzhauser W. 2019. Relationship between the probability of veterinary-diagnosed bovine mastitis occurring and farm management risk factors on small dairy farms in Austria. J Dairy Sci. 102(5):4452–4463.

Fontanelli RS, Sollenberger LE, Littell RC, Staples CR. 2005. Performance of lactating dairy cows managed on pasture-based or in freestall barn-feeding systems. J Dairy Sci. 88(3):1264–1276.

Gösling M, Klocke D, Reinecke F, Zoche-Golob V, Tho Seeth M, PAduch JH, Krömiker V. 2019. Pasteure-associated influence on the udder health of dairy herds in Northern Germany. Milk Sci Inter. 72:2–10.

Heikkilä AM, Nousiainen JI, Pyörälä S. 2012. Costs of clinical mastitis with special reference to premature culling. J Dairy Sci. 95(1):139–150.

Heringslo B, Klemetsdal G, Ruane J. 2000. Selection for mastitis resistance in dairy cattle: a review with focus on the situation in the Nordic countries. Livest Prod Sci. 64(2–3):95–106.

Hofstetter P, Frey HJ, Gazzarin C, Wyss U, Kunz P. 2014. Dairy farming: indoor v. pasture-based feeding. J Agric Sci. 152(6):994–1011.

Horn M, Steinwidder A, Pfister R, Gasteiner J, Vestergaard M, Larsen T, Zollitsch W. 2014. Do different cow types respond differently to a reduction of concentrate supplementation in an Alpine low-input dairy system? Livest Sci. 170:72–83.

Ivemeyer S, Smolders G, Brinkmann J, Gratzer E, Hansen B, Henriksen BIF, Huber J, Leeb C, March S, Mejdell C, et al. 2012. Impact of animal health and welfare planning on medicine use, herd health and production in European organic dairy herds. Livest Sci. 145(1–3):63–72.

Koifer J. 2012. Monitoring der Klauengesundheit in Milchviehherden und Funktionelle Klauenpflege (German) [Monitoring of claw health in dairy cattle herds and claw care] S. Tierärztetagung 7–8.

Koivula M, Mäntysaari EA, Negussie E, Serenius T. 2005. Genetic and phenotypic relationships among milk yield and somatic cell count before and after clinical mastitis. J Dairy Sci. 88(2):827–833.
Kromker V, Leimbach S. 2017. Mastitis treatment – reduction in antibiotic usage in dairy cows Reprod. Reprod Dom Anim. 52(Suppl. 3):21–29.

Kühl S, Flach F, Gauly M. 2020. Economic assessment of small-scale mountain dairy farms in South Tyrol depending on feed intake and breed. Ital J Anim Sci. 19(1):41–50.

Landers TF, Cohen B, Wittum TE, Larson EL. 2012. A review of antibiotic use in food animals: perspective, policy, and potential. Public Health Rep. 127(1):4–22.

Martin P, Barkema HW, Brito LF, Narayana SG, Miglior F. 2012. A review of the effects on fertility of seasonally calving grazing dairy cows supplemented with concentrates. J Dairy Sci. 96(9):5682–5697.

Rueegg PL. 2017. A 100-year review: mastitis detection, management, and prevention. J Dairy Sci. 100(12):10381–10397.

Sennereiverband. 2017. Unsere Milch unsere Zukunft. Nachhaltigkeit in der Südtiroler Milchwirtschaft (German) [Sustainability in the South Tyrolean Dairy Sector]. [accessed 2021 Feb 23]; https://www.suedtirolermilch.com/ueber-milch/sennereiverband-suedtirol/

Vanhoudt A, van Hees-Huijps K, van Kegels T, Sampimon OC, Vernooij JCM, Nielen M, van Werven T. 2018. Effects of reduced intramammary antimicrobial use during the dry period on udder health in Dutch dairy herds. J Dairy Sci. 101(4):3248–3260.

Vasquez AK, Nydam DV, Capel MB, Eicker S, Virkler PD. 2017. Clinical outcome comparison of immediate blanket treatment versus a delayed pathogen-based treatment protocol for clinical mastitis in a New York dairy herd. J Dairy Sci. 100(4):2992–3003.

WHO. 2019. Critically important antimicrobials for human medicine. 6th revision. Geneva: World Health Organization. Licence: CC BY-NC-SA3.0IGO.

Zanon T, König S, Gauly M. 2020. A comparison of animal-related figures in milk and meat production and economic revenues from milk and animal sales of five dairy cattle breeds reared in Alps region. Ital. J. Anim. Sci. 19(1):1319–1329.