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Benchmarking claw health across three dairy cow breeds in 508 dairy farms using numerical claw health indicators

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ABSTRACT

Currently, prevalence and incidence of claw lesions are used as parameters for benchmarking claw health. The aims of this study were to create a benchmarking system for claw health utilizing the claw health indicators Farm-Claw-Score (FCS) for the herd and Cow-Claw-Score (CCS) for the individual animal, and to benchmark claw health of the three predominant dairy cattle breeds in Austria. Claw health data from 17,642 cows from 508 Austrian dairy farms were analyzed. The CCS and FCS were calculated based on recorded claw lesions and their three severity levels using geometrically weighted scoring. The FCS of each of the dairy farms was classified into five percentile thresholds (P10, P25, P50, P75, P90), with the FCS calculated using the median value of CCS in each herd. Furthermore, claw health was benchmarked for three breeds (Fleckvieh, Holstein, Brown Swiss cows), using claw lesion prevalences and CCS values.

When the median FCS was calculated, dairy farms in P50 and below had an FCS of 20.0, indicating very good claw health. However, P90 farms showed an FCS-MEDIAN of 67.5. Evaluation of the prevalences of the 14 claw lesions considered and the CCS values revealed that Fleckvieh cows (CCS-MEDIAN: 24.0), followed closely by Holstein cows (CCS-MEDIAN: 22.7) had significantly poorer claw health ($P < 0.0001$) compared to Brown Swiss cows (CCS-MEDIAN: 12.0). The use of CCS and FCS as primary claw health indicators allowed for a quick assessment of the current state of an individual cow and a dairy herd in a benchmarking system. Detailed information on the claw health of each animal and the dairy herd can be easily reviewed by examining diagnosis lists that display prevalences, particularly those related to lameness, in the respective electronic documentation systems.

Introduction

Painful claw disorders and resulting lameness in dairy cows are significant causes of reduced animal welfare. Approximately 80–90 % of lameness cases in dairy cows can be attributed to lesions or malformations in claws and digits (Fenster et al., 2024). Based on their etiology, claw disorders can be divided into non-infectious (pressure-related) claw horn lesions, infectious claw diseases (Machado et al., 2010; Refaai et al., 2013), and predominantly genetically determined claw deformities such as corkscrew, scissor and asymmetrical claws (Van Amstel, 2017). The prevalence of claw lesions in dairy cows has been reported by numerous authors with the highest frequency being white-line disease, sole hemorrhage, digital dermatitis, heel horn erosion and sole ulcers (Wenz and Giebel, 2012; Sogstad et al., 2012; Fürmann et al., 2024).

In several countries claw lesions have been recorded by professional hoof trimmers for many years at each hoof trimming visit using electronic documentation systems (Kofler, 2013). In Austria, the electronic documentation program 'Klauenmanager' (SEG Informationstechnik GmbH, Bad Ischl, Austria) has been widely used for over 14 years (Kofler et al., 2011; 2022). It allows the documentation of claw lesions in 10 zones per claw, each with three levels of severity. Since 2017 electronically recorded claw lesions on farms can be collected centrally by the Cattle Data Network (RDV: https://www.rdv-gmbh.net/) (ZAR, 2017).

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In addition to displaying the prevalence of claw lesions, this program also enables the calculation of two numerical key figures. They condense the claw health of an individual animal into the Cow-Claw- Score (CCS) and that of a herd into the Farm-Claw-Score (FCS) (Huber et al., 2004; Kofler et al., 2011). The CCS is defined as the sum of all geometrically weighted claw scores of the 10 zones on the eight main claws of a cow. The FCS is defined as the median of all CCS of all animals in a herd documented during herd hoof trimming (Kofler et al., 2011; Kofler, 2013).

To create the claw health indicators CCS and FCS, recorded claw lesions considering three different levels of severity (mild, moderate severe) were subjected to geometric weighting (Greenough and Vermunt, 1991; Leach et al., 1998; Huber et al., 2004). This was done to reflect the greater clinical significance of moderate and severe claw lesions, especially those that are painful, and their stronger impact on animal welfare (Tadich et al., 2010; Sogstad et al., 2012). The arithmetic severity scores (mild, moderate severe) were then converted to geometrically weighted scores (Leach et al., 1998). After establishing standardized terminology for claw lesions in the ICAR claw health atlas (Egger-Danner et al., 2015) recent modifications have been made to these geometrically weighted scores (Kofler et al., 2023) because the original list from 2011 (Kofler et al., 2011) did not include all ICAR claw lesions.

Meanwhile, benchmarking has become an important tool worldwide for assessing farm animal welfare and management indicators in food animals (Sandgren et al., 2009; Amos et al., 2021; Poulopoulou et al., 2023). Recently, a benchmarking system for claw health was established in Switzerland using the electronic documentation system 'Klaue' (dsp Agrosoft, Ketzin, Germany) (Huber et al., 2021; Jury et al., 2021). In Austria a different documentation system called 'Klauenmanager' is used (Kofler et al., 2022). In these studies, the prevalences and incidences of various claw lesions (Huber et al., 2021; Jury et al., 2021; Kofler et al., 2022) as well as lameness incidences and premature culling due to lameness (Kofler et al., 2022) were used as parameters for benchmarking claw health in dairy cows. However, differences between individual dairy breeds or farming systems were not considered in these reports. The use of a single number reflecting the claw health of an individual cow and the herd, instead of prevalences or incidences of various claw lesions, has not been previously described for benchmarking claw health.

Therefore, the first objective of the present study was to develop a benchmarking system for claw health that utilizes the claw health indicator FCS for classification of dairy farms in percentiles. The second aim was to assess whether benchmarking claw health using the individual claw health indicator CCS could detect differences in claw health among the three most prevalent dairy cattle breeds (Fleckvieh, Holstein, Brown Swiss) in these 508 Austrian dairy farms.

Materials and methods

The anonymized and validated data sets containing documented claw lesions from 17,838 cows on 512 Austrian dairy farms were provided for this evaluation by ZuchtData (ZuchtData EDV-Dienstleistungen GmbH, Vienna, Austria). These data sets were collected in the year 2020 by 31 hoof trimmers as part of the 'Klauen-Q-Wohl' project (ZAR, 2017; Kofler et al., 2022). Four of the 512 dairy farms were excluded from the present analysis because the data included records from the 'Klauen-Profi' app (https://www.rinderzucht.at/app/klauenprofi.html), which does not differentiate between the three levels of severity for individual claw lesions.

In the remaining 508 dairy farms, 198,002 claw documentations were recorded from a total of 17,642 cows of various breeds. The raw data were transferred and sorted by farm (anonymized) using the Microsoft Excel 2020 program (Microsoft Corp., Redmond, WA, USA) for further processing in Excel tables. In these tables, the individual cows (anonymized), their breed, date of each hoof trimming, type of claw lesion, its severity level (mild, moderate, severe), affected claws and location of the claw lesion in one of the 10 claw zones (Kofler et al., 2011) were grouped for each cow and farm.

The criteria for including claw health data in the current evaluation were described in detail in a recently published study addressing various other questions (Kofler et al., 2022). The criteria were as follows:

- Only claw lesions from cows in Austrian dairy herds in 2020 were considered, documented by hoof trimmers participating in the 'Klauen-Q-Wohl' project. These hoof trimmers had achieved weighted Cohen's kappa values of ≥ 0.61 in an interobserver reliability test (Kofler et al., 2022).
- Data from dairy herds were included only if at least 50 % of the cows, based on the mean number of cows per farm, had been trimmed during the hoof trimming visits (on average two visits per year).
- Claw lesions selected had to pass tests for animal ID plausibility, recording date accuracy, and lesion code validity.
- Claw lesions from cows in dairy herds recorded exclusively using the 'Klauenmanager' documentation system were considered. This system categorized lesions into three levels of severity (mild, moderate, severe). Data from the 'Klauen-Profi'® app were not included as they did not differentiate into three severity levels.
- Data sets had to adhere to published guidelines (ICAR, 2022), including documentation of cattle without claw lesions and a minimum of five different claw lesions per farm.

Calculation of claw health indicators for each individual cow and the herd regardless of breed

Claw health was initially assessed by determining the prevalence of individual claw lesions. The prevalence of claw lesions was calculated as the percentage of cattle with at least one documented claw lesion per average number of cows per year on each farm in 2020, using the formula (Kofler et al., 2022):

$$\frac{\text{New cases of a specific claw lesion within 365 days}}{\text{Total (mean) number of cows present in the herd within 365 days}}$$

Information on the average number of cows per year on each farm in 2020 could be retrieved from the Cattle Data Base (RDV). Given that hoof trimming visits occurred approximately twice a year on these farms, each claw lesion identified during these visits was considered a new lesion (ICAR, 2022).

In the first step, the prevalence of claw lesions was calculated for all cows on these 508 farms, regardless of breed. For the calculation of the prevalence of digital dermatitis (DD), only farms that were endemically infected with DD ($n = 286$) were used. In this context, it is important to note that in Austria, approximately 50 % of dairy herds are currently still DD-free (Kofler et al., 2022).

In a second step, the claw health of cows from 508 dairy herds was assessed using the CCS and the FCS. These claw health indicators were calculated using the data provided with the help of Excel tables. Geometrically weighted scores for all claw lesions, according to the ICAR code (Egger-Danner et al., 2015), and their documented three levels of severity were used as listed in detail in the publication by Kofler et al. (2023) (Supplementary file). The geometrically weighted scores applicable to the recorded claw lesions with the specified severity were inserted into the Excel table and summed, so that a CCS value was obtained for each cow. If a cow had multiple hoof trimming visits documented in the year 2020, the CCS values collected per cow and per visit were summed and divided by the number of trimming visits. The claw health indicator per herd was calculated by determining the median value of all CCS values of the cows in a herd (FCS-MEDIAN) (Kofler et al., 2011).

Benchmarking herd claw health using the Farm-Claw-Score

To benchmark the claw health of the 508 herds evaluated, their

calculated FCS was classified into five percentile thresholds of 10 % (P10), 25 % (P25), P50 % (P50 = median), 75 % (P75) and 90 % (P90). The minimum and maximum values were also determined using the Microsoft Excel function (Microsoft Corp., Redmond, WA, USA). The FCS at the 50th percentile (median) was defined as the benchmark cut-off threshold in this study.

Breed-specific benchmarking of claw health in Fleckvieh, Holstein and Brown Swiss cows using claw lesion prevalences and Cow-Claw-Scores

The data sets submitted also included information on the breed of the dairy cows. The cows were classified according to the three main breeds found in Austria (Fleckvieh = dual-purpose Simmental, Holstein and Brown Swiss), regardless of their farm of origin. For this breed-specific analysis, data from all the 508 farms were used, however cows that did not belong to one of these three main breeds were excluded. This resulted in a total of 17,099 cows available for breed-specific evaluation of claw lesions and CCS: 12,566 Fleckvieh cows from 402 farms, 2704 Holstein cows from 52 farms and 1829 Brown Swiss cows from 54 farms.

First, the prevalence of claw lesions in 2020 was calculated for cows based on their respective breeds. Next, the previously calculated CCS values for each cow were sorted, and the CCS values of the cows from the three breeds were classified into percentiles P10, P25, P50 (median), P75, P90 and the minimum and maximum values. This allowed for a comparison of claw health among the three breeds.

Statistical analyses

The evaluation of potential differences in claw health, as described by CCS values, among cows of three different breeds was conducted using the procedure glimmix (SAS version 9.4, SAS Institute Inc., Cary, NC, USA) with lognormal distribution and identity link function at a significance level of $\alpha = 0.05$. Before the analysis, a value of 1 was added to all CCS values as zero values cannot be log transformed. The model included the fixed effect of breed and the random effect of farm. For additional pairwise comparisons between breeds, the implemented Tukey-Kramer method was applied as a correction for multiple testing ($\alpha_m = 0.05$).

Results

To benchmark claw health using numerical key indicators (CCS, FCS), a total of 198,002 claw health data from a total of 17,642 cows of various breeds across 508 dairy herds, collected in 2020, were analyzed. These cows came from 376 free-stall farms (74.0 %) and 132 tie-stall farms (25.9 %), with cows in the tie-stall farms receiving at least 90 days of exercise. The average herd size was 34.9 cows (minimum 25; maximum 163). The mean 305-day milk production was 8469.4 kg (Standard Deviation, SD 1521.5; median 8462.5) for the 12,566 Fleckvieh cows, 9865.2 kg (SD 2094.8; median 9996.4) for the 2704 Holstein cows, and 8328.2 kg (SD 1972.2; median 8094.0) for the 1829 Brown Swiss cows.

Benchmarking 508 dairy farms considering the prevalences of claw lesions in cows

The prevalences of claw lesions in cows from the 508 dairy farms, regardless of breed but considering all three levels of severity, are listed in Table 1. A significant variation in the occurrence of various claw lesions among the individual farms was observed.

The highest mean prevalences were assessed for white-line disease (WLD) (56.8 %), heel horn erosion (HHE) (48.0 %), sole hemorrhage (SH) (29.6 %), double sole (DS) (18.8 %), concave dorsal wall (CD) representing chronic laminitic claws (18.1 %) and ulcers (13.6 %; all locations combined). In the 286 farms out of 508 that had an endemic DD infection, the mean prevalence of DD at the cow level was 33.2 %.

Table 1
Prevalence of different claw lesions at cow level in 508 Austrian dairy farms in 2020, classified into percentiles P10, P25, P50 (median), P75 and P90.

Claw lesion (code)	Mean	SD	P10	P25	P50 = median	P75	P90
White-line disease (WLD)	56.8	30.4	14.6	31.9	58.1	82.3	97.0
Sole hemorrhage (SH)	29.6	27.4	0.0	7.6	23.1	45.0	67.2
Double sole (DS)	18.8	23.0	0.0	4.7	11.7	23.4	43.5
Concave dorsal wall (CD)	18.1	18.5	0.0	0.0	4.7	17.3	32.7
Ulcers (sole, toe, bulb; SU, TU, BU)	13.6	11.5	0.0	4.9	11.3	20.3	29.9
Horn fissure (HF)	2.6	4.5	0.0	0.0	0.0	4.2	8.5
Horn fissure axial (HFA)	1.4	3.4	0.0	0.0	0.0	0.0	5.1
Thin sole (TS)	0.7	4.8	0.0	0.0	0.0	0.0	0.0
Heel horn erosion (HHE)	48.0	39.2	7.8	12.8	40.2	87.3	98.2
Digital dermatitis (DD)[a]	33.2	25.9	5.4	9.5	25.4	52.2	75.7
Interdigital phlegmon (IP; foot rot)	0.8	2.0	0.0	0.0	0.0	0.0	3.0
Swelling of coronet and/or bulb (SW)	1.9	5.7	0.0	0.0	0.0	0.0	4.9
Interdigital hyperplasia (IH)	5.0	7.3	0.0	0.0	2.4	7.5	13.4
Corkscrew claw (CC)	8.3	4.5	0.0	0.0	2.9	9.6	25.9

SD, standard deviation.
[a] Data for digital dermatitis prevalence among herds is derived only from herds with endemic DD (n=286). Taking into account the data from all 508 herds, the prevalence of DD would have been yielded the following results: 18.6 (mean), 25.9 (SD), 0.0 (P10), 0.0 (P25), 5.6 (P50), 31.0 (P75), and 59.7 (P90).

Benchmarking claw health on the 508 farms in the year 2020 revealed that in cows on the P10 farms, representing the class with the best claw health, numerous claw lesions (such as ulcers, SH, DS, HF, CD, corkscrew claw [CC], interdigital phlegmon/'footrot' [IP], swelling of the coronet or bulb [SW], or interdigital hyperplasia [IH]) had not been recorded at all, and that the remaining claw lesions showed a low prevalence ranging from 5.4 % to 14.6 % (Table 1).

Benchmarking claw health on 508 dairy farms using Farm-Claw-Score

The calculated FCS-MEDIAN values of the 508 individual dairy farms showed a large variance, ranging from a minimum value of 0.0 to a maximum value of 337. Further classification was done in percentiles, with the FCS-MEDIAN ranging from 0.0 (P10) to 67.5 (P90). The median (P50) was 20.0. (Table 2).

If the threshold value for good claw health is set at the FCS-MEDIAN of 20.0, corresponding to the median when evaluating these 508 dairy farms, then the farms up to P50 fall below this threshold (Table 2; Fig. 1). If the threshold value for good claw health is set at the FCS-MEDIAN of 30.0, as proposed in former studies (Kofler et al., 2013; Burgstaller et al., 2016) where 66.7 % of farms had an FCS <30 (Kofler et al., 2013), and by Steiner (2023) with the FCS-MEAN of 30.9, then the farms up to P64 (for the FCS-MEDIAN) are covered by this adapted threshold value.

Table 2
Summary statistics showing percentiles (P10, P25, P50, P75 and P90) as well as the minimum (Min) and maximum (Max) values of the Farm-Claw-Score (FCS) values of all dairy farms.

	Min	Max	P10	P25	P50	P75	P90
FCS	0.0	337.0	0.0	8.0	20.0	38.0	67.5

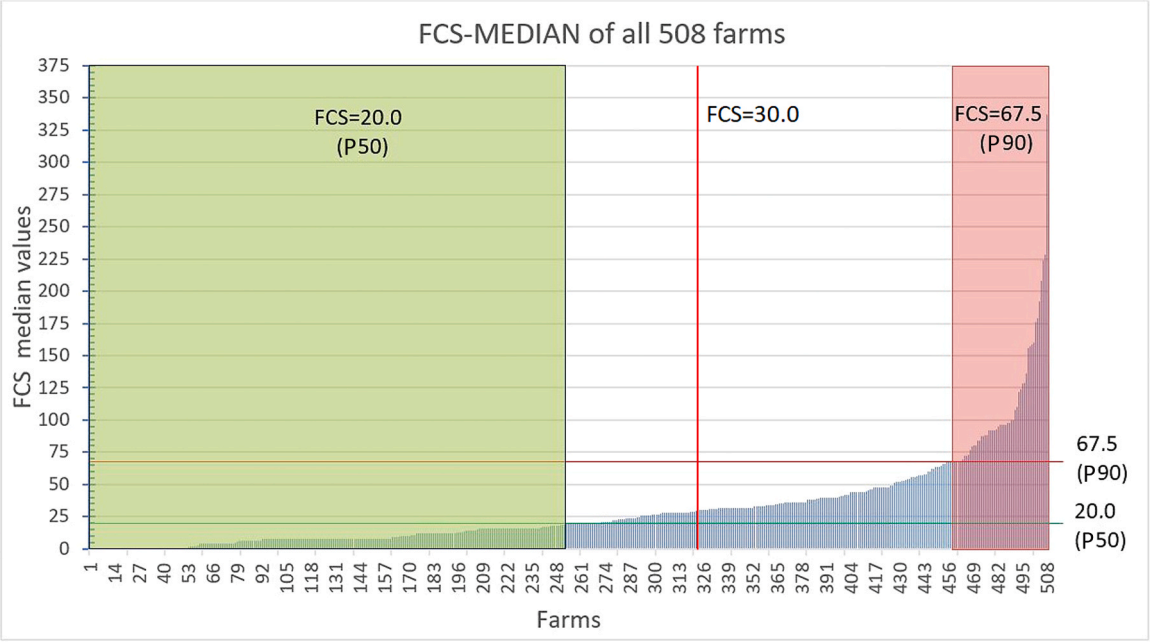

Fig. 1. The column chart displays the distribution of the FCS-MEDIAN for the 508 farms; farms up to P50 (FCS-MEDIAN = 20.0) are marked in green, while farms in P90 are marked in red. The red vertical line indicates the threshold of FCS = 30.0; FCS, Farm-Claw-Score; P, percentile.

Benchmarking claw lesion prevalences in Fleckvieh, Holstein and Brown Swiss cows

The prevalences of claw lesions and their classification into percentiles for Fleckvieh, Holstein and Brown Swiss cows are presented in Tables 3–5. Fleckvieh cows exhibited higher prevalences of WLD, SH, DS, HHE and corkscrew claws compared to the other two breeds. On the other hand, the prevalence of DD was noticeably higher in Holstein cows than in the other two breeds across all 508 dairy herds. These breed differences were also apparent when comparing P10 and P25, particularly for WLD, ulcers, and DD (Tables 3–5).

Table 3
Prevalence of 14 different claw lesions in 12,566 Fleckvieh cows across all 508 herds in 2020, classified into percentiles P10, P25, P50 (median), P75 and P90.

Claw lesion (Code)	Mean	SD	P10	P25	P50 = median	P75	P90
White-line disease (WLD)	59.2	29.2	19.1	36.2	60.0	84.1	97.0
Sole hemorrhage (SH)	30.9	26.8	0.0	9.3	25.0	45.2	68.2
Double sole (DS)	19.1	23.5	0.0	4.8	11.7	23.4	45.0
Concave dorsal wall (CD)	10.8	15.4	0.0	0.0	4.6	16.1	31.1
Ulcers (sole, toe, bulb; SU, TU, BU)	12.4	11.0	0.0	4.1	9.7	18.2	28.7
Horn fissure (HF)	2.4	4.3	0.0	0.0	0.0	3.9	7.0
Horn fissure axial (HFA)	1.2	3.3	0.0	0.0	0.0	0.0	4.6
Thin sole (TS)	0.7	4.9	0.0	0.0	0.0	0.0	0.0
Heel horn erosion (HHE)	48.3	38.4	4.8	13.2	40.7	84.6	98.8
Digital dermatitis (DD)	30.2	21.7	5.4	7.5	23.4	47.2	71.2
Interdigital phlegmon (IP; foot rot)	0.7	1.9	0.0	0.0	0.0	0.0	2.7
Swelling of coronet and/or bulb (SW)	2.0	6.2	0.0	0.0	0.0	0.0	4.9
Interdigital hyperplasia (IH)	4.6	6.9	0.0	0.0	2.2	7.0	12.3
Corkscrew claw (CC)	8.9	15.0	0.0	0.0	2.5	11.0	30.5

SD, standard deviation.

Table 4
Prevalence of 14 different claw lesions in 2704 Holstein cows across all 508 herds in 2020, classified into percentiles P10, P25, P50 (median), P75 and P90.

Claw lesion (Code)	Mean	SD	P10	P25	P50 = median	P75	P90
White-line disease (WLD)	36.6	26.5	4.4	17.0	32.5	55.7	76.8
Sole hemorrhage (SH)	20.0	19.8	0.0	2.1	17.9	3.0	44.6
Double sole (DS)	14.3	20.2	1.4	4.0	7.8	17.5	28.4
Concave dorsal wall (CD)	7.0	11.8	1.9	5.2	10.2	23.4	41.1
Ulcers (sole, toe, bulb; SU, TU, BU)	12.8	9.6	1.7	5.8	10.8	19.4	25.5
Horn fissure (HF)	2.8	4.3	0.0	0.0	0.0	3.8	8.1
Horn fissure axial (HFA)	1.2	2.2	0.0	0.0	0.0	1.5	5.0
Thin sole (TS)	1.0	5.3	0.0	0.0	0.0	0.0	1.5
Heel horn erosion (HHE)	35.4	35.9	4.5	12.8	24.7	58.7	88.0
Digital dermatitis (DD)	35.6	29.3	5.3	8.4	28.2	59.7	74.3
Interdigital phlegmon (IP; foot rot)	0.5	1.3	0.0	0.0	0.0	0.0	1.9
Swelling of coronet and/or bulb (SW)	1.4	4.0	0.0	0.0	0.0	1.5	3.2
Interdigital hyperplasia (IH)	7.1	8.6	0.0	0.0	4.8	10.2	16.9
Corkscrew claw (CC)	7.1	9.9	0.0	0.0	3.2	7.5	21.5

SD, standard deviation.

Benchmarking claw health using CCS in Fleckvieh, Holstein and Brown Swiss cows

Benchmarking the claw health of cows from the three breeds using CCS values revealed obvious differences among the breeds. The percentile thresholds for the three breeds were as follows: P10 with a

Table 5
Prevalence of 14 different claw lesions in 1829 Brown Swiss cows across all 508 herds in 2020, classified into percentiles P10, P25, P50 (median), P75 and P90.

Claw lesion (Code)	Mean	SD	P10	P25	P50 = median	P75	P90
White-line disease (WLD)	32.3	19.2	5.9	20.9	31.0	42.7	55.7
Sole hemorrhage (SH)	13.5	14.5	0.0	2.8	10.0	17.5	35.5
Double sole (DS)	11.3	12.9	0.0	4.2	8.4	16.3	21.1
Concave dorsal wall (CD)	9.5	10.3	1.5	4.9	14.2	23.2	33.8
Ulcers (sole, toe, bulb; SU, TU, BU)	12.3	9.2	0.0	4.7	11.1	20.9	24.1
Horn fissure (HF)	2.6	3.5	0.0	0.0	0.7	4.1	8.7
Horn fissure axial (HFA)	1.6	2.9	0.0	0.0	0.0	2.5	5.1
Thin sole (TS)	0.1	0.5	0.0	0.0	0.0	0.0	0.0
Heel horn erosion (HHE)	28.8	29.4	3.5	4.9	20.4	40.7	71.1
Digital dermatitis (DD)	24.2	21.6	3.3	5.4	23.3	35.7	54.6
Interdigital phlegmon (IP; foot rot)	0.3	0.9	0.0	0.0	0.0	0.0	1.6
Swelling of coronet and/or bulb (SW)	0.8	2.3	0.0	0.0	0.0	0.0	1.9
Interdigital hyperplasia (IH)	2.3	3.5	0.0	0.0	0.0	4.6	6.6
Corkscrew claw (CC)	6.0	8.9	0.0	0.0	3.8	9.2	13.3

SD, standard deviation.

CCS of 0.0, P25 with a CCS 5.0, P50 with a CCS of 21.3, P75 with a CCS of 64.0, and P90 with a CCS ≥ 136.0. The highest CCS recorded was 976.

In P10 there were 29.5 % of Brown Swiss cows, 23.3 % of Holstein cows and only 15.3 % of Fleckvieh cows. 60.3 % of the Brown Swiss cows were in P50, which is the median with a CCS value of 21.3, whereas only 48.5 % of Fleckvieh and 49.3 % of Holstein cows were present in this category (Fig. 2).

Comparisons of CCS values in the three dairy cattle breeds

When comparing the log-transformed CCS values of Fleckvieh, Holstein and Brown Swiss cows, significant differences were observed ($P < 0.0001$) (Table 6). Median CCS values were 24.0, 22.7 and 12.0 for Fleckvieh, Holstein and Brown Swiss cows, respectively. Additional pairwise comparisons conducted with the Tukey-Kramer correction revealed that both Fleckvieh and Holstein breeds had significantly higher CCS values compared to Brown Swiss; however, Fleckvieh and Holstein cows did not differ significantly in terms of CCS values ($P = 0.068$).

Discussion

The benchmarking process used in this study enables the classification of many dairy herds using percentile cut-offs, starting with the best in class, the farms in P10 through P25, P50 (median), P75 and up to the worst-rated farms in P90 (Sandgren et al., 2009). In the benchmarking system, the best-in-class (P10 - P25) farms act as role models demonstrating to other farms how low the prevalence/incidence of selected health parameters can be with excellent conditions and management (Amos et al., 2021; Dachrodt et al., 2022; Poulopoulou et al., 2023).

For data analysis in the current study, as well as in a previous benchmarking study on claw health (Kofler et al., 2022), only data from the 31 hoof trimmers who achieved a weighted Cohen's kappa value of ≥ 0.61 in a completed inter-observer reliability test were included. This level of agreement with a Cohen's kappa value of ≥ 0.61 has been recognized as the minimum requirement for utilizing claw health data by other researchers (Jury et al., 2021).

A list of individual claw lesion prevalences is readily available after each herd hoof trimming session to professional hoof trimmers who utilize an electronic documentation system, as well as to their customers, farmers and collaborating farm veterinarians (Kofler et al., 2011; Wenz and Giebel, 2012). The advantage of listing the prevalence

Table 6
Least squares means (LSMean) and their standard errors (SE) for the effect of breed on the log-transformed[a] CCS values. Different superscript letters indicate significant differences after Bonferroni-Holm correction ($\alpha_m = 0.05$).

Breed	LSMean	SE
Fleckvieh	2.936[a]	0.045
Holstein	2.810[a]	0.065
Brown Swiss	2.615[b]	0.071

[a] value of 1 added to all CCS values before log-transformation.

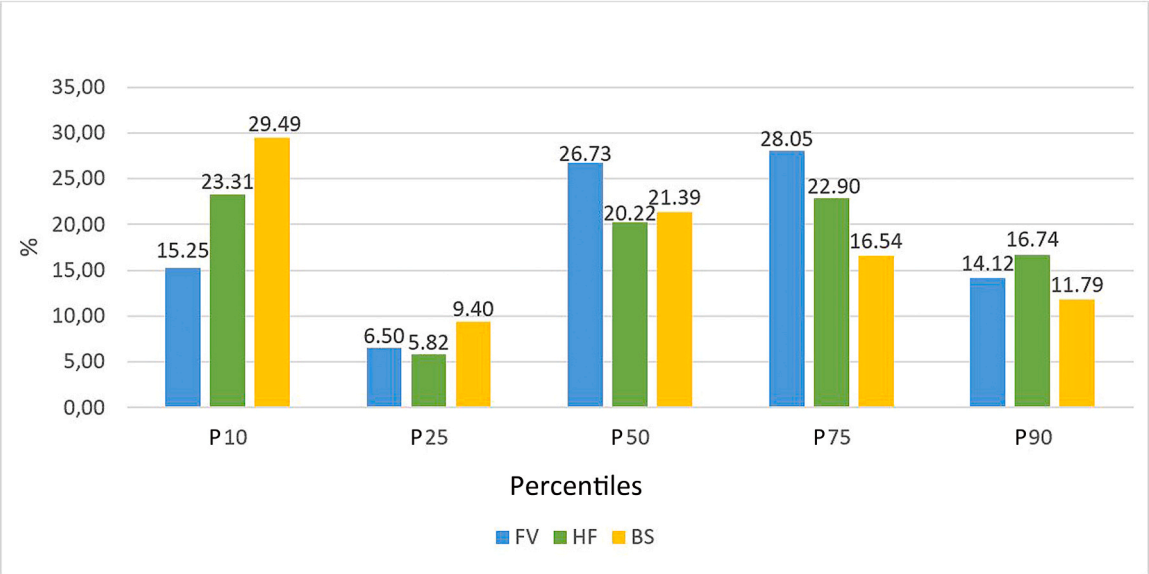

Fig. 2. Bar chart depicting benchmarking of claw health using the CCS values for Fleckvieh (FV), Holstein (HF) and Brown Swiss (BS) cows in the defined claw health classes (P10, P25, P50, P75, P90).

of claw lesions recorded in an individual cow or in a herd is the detailed overview of which claw lesion types (infectious and non-infectious) are occurring and with what frequency. However, interpreting such a list with prevalences of 14 or more different claw lesions requires profound knowledge on the part of the farmer, the hoof trimmer, and the veterinarian about the clinical significance of the individual lesion. This includes background knowledge of which lesions always cause pain, leading to lameness, and which either do not cause pain at all or are rather rare, and knowledge of suitable control measures based on the prevalence of the lesion type (Tadich et al., 2010; Sogstad et al., 2012; Jewell et al., 2021).

Another option for comparing claw health is to use geometrically weighted claw health indicators in the form of the CCS for the individual animal and the FCS for the herd, which can be calculated from the documented claw lesions and their respective levels of severity (Kofler et al., 2023). The geometric weighted scoring of claw lesions and their three levels of severity is based on the well-known and frequently described fact that not every claw lesion and not all DD stages are associated with pain and lameness, therefore having varying effects on animal welfare (Tadich et al., 2010; Sogstad et al., 2012; Jewell et al., 2021).

These recently adapted weighted geometric scores for claw lesions (Kofler et al., 2023) were developed in cooperation with Swiss researchers from Berne (Adrian Steiner and Claudia Syring), who use the electronic documentation system 'Klaue' (dsp Agrosoft, Ketzin, Germany) (Steiner, 2023), which does not consider the 10 claw zones. Hence, these established weighted geometric scores can now also be utilized when other electronic documentation systems are applied. Therefore, in the future, evaluations of cattle herd claw health can be more easily compared on an international scale. With the assistance of a single number, the claw health indicator of a cow or a farm, veterinarians, hoof trimmers and farmers can quickly gain an overview of the claw health of individual cows and farms. This can be useful for monitoring the claw health of a herd over time (Kofler, 2013), for comparing the claw health of many farms (Kofler et al., 2013; Burgstaller et al., 2016; Steiner, 2023), and for scientific trials (Kofler et al., 2023). Thus, the use of CCS and FCS may represent a more sensitive method to evaluate treatment and management measures carried out in a herd regarding their positive impact on claw health, rather than exclusively relying on the prevalence of up to 14 different claw lesions (Burgstaller et al., 2016; Kofler et al., 2023). This method is similar to using somatic cell count in the bulk milk as a parameter to evaluate the udder health of a herd (Kofler et al., 2013).

The higher the CCS of a cow, the worse is her claw health. Correspondingly, the higher the FCS, the worse the claw health of all hoof-trimmed and documented cattle in a herd (Huber et al., 2004; Kofler, 2013; Burgstaller et al., 2016). The results of benchmarking these 508 dairy farms using the FCS can be interpreted as follows: The FCS-MEDIAN was 20.0, which is considered very good based on previous comparisons of claw health, therefore this FCS-MEDIAN value was used as cut-off. In previous studies, an FCS and CCS of < 30.0 were classified as good claw health (Kofler et al., 2013; Burgstaller et al., 2016). In the present study, we used an FCS of 20 as the cut-off threshold because the median of 508 farms yielded this value. However, it is worth noting that previous studies have suggested an FCS value of 30 as the cut-off, albeit with a maximum of 15 herds examined only (Kofler et al., 2011; 2013; Burgstaller et al., 2016). This is why the comparison value of FCS 30 was included in the column chart of Fig. 1. To illustrate the small difference between the FCS values of 20 and 30, it should be noted that a weighted score difference of 10 corresponds to one additional mild heel horn erosion and one additional moderate double sole per cow (Kofler et al., 2023).

In the trials mentioned, researchers conducted locomotion scoring of cattle, electronically documented claw lesions during hoof trimming visits on the farms and analyzed the environmental conditions themselves. This provided the researchers with a comprehensive understanding of claw health directly on the visited farms. Subsequently, they calculated and compared the prevalences of documented claw lesions and the corresponding CCS values. Therefore, based on the knowledge of the overall situation in these examined farms, they could conclude that a CCS (and FCS-MEDIAN) of less than 30 would indicate good claw health in an individual cow and in a herd (Kofler et al., 2011; 2013; Burgstaller et al., 2016).

In a similar assessment of around 1000 dairy farms in Switzerland, a farm value of 30.9 for claw health, calculated as a mean, was proposed as the threshold between the tolerance range ($>$ P10 to $<$ P90) and farms in P90 (Steiner, 2023). Farms with an FCS-MEAN > 30.9, corresponding to P90, were considered to have poor claw health (Steiner, 2023). In farms that exceeded the threshold value and had poor claw health, immediate action should be taken with involvement of the farm veterinarian and the national animal health service to significantly improve claw health over a period of approximately 12 months (Huber et al., 2021; Jury et al., 2021; Steiner, 2023). Researchers have identified an FCS-MEDIAN < 30 (Kofler et al., 2011; 2013; Burgstaller et al., 2016) or an FCS-MEAN of < 30.9 (Steiner, 2023) as the target value for benchmarking dairy farms. If the threshold value of 30 (FCS-MEDIAN) were applied to the results in the current study, farms from P64 onwards would be classified as having moderate to poor claw health.

In the case of a right-skewed distribution, as evidenced by the FCS values in the current study (Table 1), the median is preferred (Sapra, 2022), which is in contrast to a Swiss study were the FCS-MEAN was used (Steiner, 2023). The approach of using the FCS-MEDIAN was also taken in all our previous studies (Kofler et al., 2011, 2013; Burgstaller et al., 2016) because it offers a more realistic interpretation of the data distribution. When values are skewed to the right, the mean is usually much larger than the median (Sapra, 2022).

Recently, it has been suggested that to specify benchmarking for claw health and to compare claw health, only data from cows on farms with the same breed, housing conditions (freestall, tie-stalls) and similar milk production levels should be used (Kofler et al., 2022). Therefore, breed-specific benchmarking was conducted, despite obvious differences in the numbers of the three cattle breeds considered. Fleckvieh cows showed higher prevalences of WLD, SH, DS, HHE and corkscrew claws compared to the other two breeds. However, in Holstein cows, the prevalence of DD was distinctly higher than in the other two breeds. These breed differences were also apparent when comparing P10 and P25, particularly in cases of WLD, ulcers and DD. Evaluation of claw health in cows from these three breeds using the CCS also revealed that across the 508 herds evaluated, 60.1 % of Brown Swiss cows were classified in P50, while only 48.2 % of Fleckvieh and 48.9 % of Holstein cows fell into this category. Statistical analysis indicated that in 2020, Brown Swiss cows had significantly better claw health compared to Fleckvieh and Holstein cows. Despite slightly better results for Holstein cows in terms of distribution in the percentiles and prevalence of some claw lesions, no significant difference in claw health, calculated according to CCS values, could be determined between Fleckvieh and Holstein cows. Other studies have also reported that Brown Swiss cows showed significantly lower prevalences of claw lesions and lameness compared to Fleckvieh and Holstein cows (Becker et al., 2014; Jury et al., 2021). In a recently published study from Switzerland, Holstein cows were attributed with a significantly higher risk of developing DD than other breeds, although Holstein cows had a lower risk of developing WLD compared to other breeds (Fürmann et al., 2024). Our study confirmed that Holstein cows had a distinctly lower prevalence of 36.6 % for WLD compared to 59.2 % for Fleckvieh cows. Additionally, Holstein cows had the highest prevalence of DD.

Limitations of the current study that must be mentioned include the fact that the cows from these 508 herds did not have the same housing conditions (loose housing systems vs. tied stalls), did not have the same milk production levels, had different lactation numbers, and came from different regions in Austria. Furthermore, the numbers of the three cattle breeds considered were very different.

In Austria, benchmarking of claw health has been implemented in the RDV herd manager (https://www.rdv-gmbh.net/) since March 2022. Claw health data are continuously fed into and processed in this Cattle Data Base. Farmers who are RDV members can compare the claw health data of their own herd with that of hundreds of other dairy farms through their online access (Kofler et al., 2022). This can contribute to increasing motivation for improving claw health on their farms. The motivation could certainly be intensified if all actors involved, such as veterinarians, hoof trimmers and farmers, make greater use of the implemented claw health benchmarking infrastructure.

Conclusions

The results of this study suggest that calculating the numerical claw health indicators CCS and FCS and using them as primary key figures in a claw health benchmarking system is well-suited to provide a rapid overview of the current state of claw health for an individual cow and a dairy herd. CCS and FCS allow for a quick and general comparison of claw health among numerous farms. However, it is also necessary for farm veterinarians, hoof trimmers and farmers themselves to obtain more detailed information on the claw health of each individual animal and the dairy herd. This can be easily achieved today by accessing the diagnosis list with the displayed prevalence of claw lesions, especially those that are always associated with pain, in the respective electronic documentation systems used by professional hoof trimmers. This will help determine which claw lesions are specifically affecting animal welfare.

CRediT authorship contribution statement

J. Kofler: Writing – original draft, Writing – review & editing, methodology, conceptualization. **P. Berger:** Writing – review & editing, methodology, investigation. **C. Egger-Danner:** Review & editing, methodology, conceptualization, investigation, **B. Fuerst-Waltl:** Writing – review & editing, methodology, conceptualization, investigation.

Institutional Review Board Statement

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Conflict of Interest

None of the authors has any financial or personal relationships that could inappropriately influence or bias the content of the paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.tvjl.2024.106242.

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