



## Evaluation of changes in calf management from 2012 to 2022 on Austrian dairy farms using an online questionnaire

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### ABSTRACT

Calf management is important for the development, health, and welfare of the animals. In this follow-up study, we evaluated calf management practices on dairy farms in Austria using an online questionnaire in 2021 and 2022. We tested the hypothesis that farmers changed calf management on their farm within these 10 years. The total number of analyzable surveys in 2022 was 2,314. All variables changed significantly between years. Therefore, farms were chosen randomly by controlling for confounding changes in herd size (number of dairy cows), farm type (conventional vs. organic), and type of cows' barn (freestall vs. tiestall). From 2012 to 2022, the median number of cows per farm increased from 20 (interquartile range [IQR] 13 to 30) to 22 (IQR 13 to 35), and the percentage of organic-producing farms increased from 23.9% (2012) to 30.6% (2022). The number of farms offering colostrum within 4 h after birth increased from 83.7% to 87.2%. This change was significant when subsampling was performed. The quantity of first colostrum offered to the newborns was mainly 2 to 4 L (69%), with an increased percentage of farms offering less than 2 L (13.3% vs. 18.3%). The percentage of farms testing colostrum quality using an objective method (hydrometer, Brix refractometer, outflow funnel) increased significantly by 4.9-fold and was 9.4% in 2022. On most farms (88.8% and 86.6% in 2012 and 2022, respectively), calves were housed individually after birth. A higher percentage reported grouping calves at an earlier age than in 2012. In both years, mainly whole milk was fed (85.1% vs. 86.3%). The number of farms where nonsalable or waste milk was fed to calves decreased significantly

from 84.0% to 74.1%. Milk allowance increased nonsignificantly. Subsampling revealed that the age at weaning increased significantly between years. The most important health problem in calves was diarrhea (in 59.8% of farms, >10% of calves; and in 27.4%, >25%), followed by respiratory tract disease (in 39.8% of farms, >10% of calves; and on 16.4%, >25%). Compared with 2012, in 2022, a significantly higher percentage of farmers stated that they had a calf diarrhea incidence of >10% (39.8% vs. 59.8%). In our study, weak points regarding calf management on farms were not offering enough first colostrum, missing testing for colostrum quality, not housing calves socially in the first weeks postnatum, and feeding restricted amounts of milk. The median mortality rate of 3% (IQR 1 to 5) and increasing diarrhea incidence also show that calf management practices need improvement. Thus, how to get farmers motivated to implement changes in their management in accordance with science-based recommendations remains an open question.

**Key words:** calf management, colostrum, housing, milk feeding

### INTRODUCTION

Calf management from birth to weaning is important for calf health, development, and well-being, as well as for the future success of the dairy farm. Particularly, colostrum management, feeding, housing, and hygiene have significant effects (Whalin et al., 2021; Grothe and Thornsberry, 2022). The European Union, Council Directive 2008/119/EC lays down minimum standards for the protection of calves. Numerous research studies are performed every year in the area of calf management, aiming to give advice on how to optimally raise calves with regard to health and well-being. In the last decade, colostrum management (e.g., reviewed by Lombard et al., 2020; Ahmann et al., 2021; Robbers et al., 2021;

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The list of standard abbreviations for JDS is available at [adsa.org/jds-abbreviations-25](https://adsa.org/jds-abbreviations-25). Nonstandard abbreviations are available in the Notes.

Lopez and Heinrichs, 2022), social housing of newborn calves (Beaver et al., 2020; Whalin et al., 2021; Nawroth and Rørvang, 2022; Sirovica et al., 2022), and intensified milk feeding strategies (Khan et al., 2016; Ockenden et al., 2023) have been well studied. These topics have also regularly been covered by journal articles and continuing education and training offered to farmers in Austria, as screened by Slamanig (2022) for the years 2015 to 2020. In this work 187 journal articles, trainings, and lectures offered in German for farmers on calf management topics during the evaluated years were identified. Calf feeding, including different topics such as milk feeding, ad libitum versus restricted milk feeding, and weaning, was covered in 37.9% of all articles and trainings. The second most frequent topic was colostrum management ( $n = 34$ ; 11.2%), with 5 articles and 8 trainings explicitly dealing with colostrum quality and testing of colostrum quality. This topic was followed by calf housing (9.6%), climatic stress (6.9%), and diarrhea (6.6%). Further topics were (in descending order) diseases other than diarrhea, mortality, general aspects of calf rearing, calf behavior, hygiene, immunity, umbilicus, homeopathy and phytotherapy, cross-sucking, dehorning, and miscellaneous.

In 2012, we conducted an online survey that examined calf management practices on Austrian dairy farms (Klein-Jöbstl et al., 2015). In that study, we identified weak points, such as colostrum management (especially testing colostrum quality and quantity of first colostrum fed), housing calves individually, and restricted milk feeding. With the present study, we aimed to detect changes in calf management on Austrian dairy farms within the last 10 years (2012 to 2022) by conducting another online questionnaire. We especially focused on areas that have been covered in continuing education of farmers on Austrian dairy farms (Slamanig, 2022).

## MATERIALS AND METHODS

### Data Collection

As in 2012 (Klein-Jöbstl et al., 2015), the study population was dairy farms registered in the Association of Austrian Cattle Breeders (Vienna, Austria) with an active email address. Overall, 67.4% of dairy farms, keeping 80.2% of the dairy cows in Austria, are members of this association. In total, the hyperlink to the questionnaire was sent to 16,246 farms via email.

The anonymous questionnaire was created with Survey Monkey (SurveyMonkey Europe UC, Dublin, Ireland). The questionnaire covered 5 areas of interest: (1) farm characteristics; (2) calving and care of the newborn; (3) calf housing; (4) calf feeding; and (5) calf disease, problems, and mortality. The survey consisted of 52 questions, with either single-choice, multiple-choice, or

open-text answers. Some questions were skipped automatically, depending on the answer given. For example, if the answer to whether colostrum quality was tested was no, the next question about the method was automatically skipped. The questionnaire (an English translation from the original German version) and, if applicable, changes in questions in 2022 compared with 2012, can be found in our supplemental material (see Notes).

The questionnaire was conducted by the authors DKJ and NH and reviewed by 5 researchers. Before the questionnaire was sent out, it was tested for comprehensibility and clarity by a limited number of farmers ( $n = 27$ ), veterinarians ( $n = 7$ ), and consultants ( $n = 6$ ). The survey was online for 8 weeks, from February to March 2022. A reminder was sent at the beginning of March to increase the number of participants.

Before sending out the questionnaire, the questionnaire per se and the cover letter, as well as the methods of gaining, using, and saving data with regard to the European General Data Protection Regulation, were approved by the Legal Department, Coordination of Data Protection, and Compliance of the University of Veterinary Medicine, Vienna, Austria.

### Data Analysis

All data provided by the system (Survey Monkey) were transferred into Microsoft Excel (Excel 2010, Microsoft Corporation) and examined individually for aberrant answers and plausibility. Furthermore, farms other than dairy farms were excluded from the data analysis. Farms with missing data in the questions on herd size (number of dairy cows), farm type (conventional vs. organic), and type of cows' barns were excluded from further statistical analysis. Additionally, if, in the areas of interest 2 to 5, more than 25% were missing, these data were also removed from further statistical evaluation. Free-text answers were summarized and categorized.

Statistical analyses were performed with SPSS (version 24, IBM Corporation). The continuous variable "number of cows" was tested for normality using the Shapiro-Wilk test, and the median and 25 and 75 percentiles were calculated. The continuous variables "milk yield" and "estimated disease incidence" were categorized in accordance with the data from 2012 (<10%, 11%–25%, 26%–50%, 51%–75%, or >75%).

The Pearson chi-squared test was used to test the statistical significance of the differences between the 2 surveys and corrected for multiple testing via the Bonferroni-Holm method. Evaluation of the raw data revealed significant differences between 2012 and 2022 for all examined variables. Consequently, due to differences in the distribution of herd size (number of dairy cows), farm type (conventional vs. organic), and the type of cows' barns (freestall vs.

tiestall) between the 2 surveys, a multivariate reweighting algorithm with 10-fold subsampling was applied to reduce the influence of those confounding variables on the results. These factors were chosen because it has been shown that farm size has a significant influence on calf management factors (Klein-Jöbstl et al., 2015). Legislation influences management on organic-producing farms. Consequently, we controlled for this in our subsampling procedure. We also controlled for the cows' barn, as this represents the cattle housing on farm. For the multivariate reweighting algorithm, an R script was written, which, in the first step, collected information about the frequency of the respective confounding variables herd size, farm type, and type of cows' barn from the 2012 survey. Those 3 frequencies were then simultaneously applied when randomly subsampling the data from both surveys, creating subsamples with the same distribution among those 3 parameters. That allowed for a direct comparison of the survey results, controlling for the 3 confounding variables. Subsampling was conducted randomly with a sample size of 220, determined through a power analysis using G\*Power 3.1.9.7 (<https://www.psychologie.hhu.de/arbeitsgruppen/allgemeine-psychologie-und-arbeitspsychologie/gpower>) calculated for chi-squared tests with a median effect size of 0.3, a type I error of 0.05, and a power of 0.95 (Serdar et al., 2021). The data preparation was executed within the R statistical environment (version 4.1.3, R Core Team, 2023), using data manipulation functions from the purrr (version 1.0.1, Wickham and Henry, 2023) and the dplyr packages (version 1.1.1, Wickham et al., 2023a). The tidy package (version 1.3.0, Wickham et al., 2023b) was employed to manage nested data structures within the subsampling workflow.

The level of significance was set at  $P < 0.05$ .

## RESULTS

Overall, we received 2,328 answers (a response rate of 14.3%), of which 14 had to be withdrawn because the farm type was other than dairy. This resulted in 2,314 analyzable surveys. In 2012, we had a response rate of 14.2% (1,501 out of 10,500) with 1,287 analyzable surveys. In the following, including tables and figures, all data presented in the descriptive statistics refer to these numbers (1,287 and 2,314 in 2012 and 2022, respectively). The tables and figures include the percentage of respondents who did not provide an answer to the question. The median of missing data per question was 2.1% (interquartile range [IQR] 0.8% to 4.4%).

### General Farm Characteristics

Among the responding farms, the percentage of organic-producing farms increased from 23.9% to 30.6%

(2012 vs. 2022). In 2012, 42.8% and in 2022, 36.9% of farms kept their cows tied, whereas in 2022, on 93% of these farms, cows had access to pasture. The milk yield on the participating farms increased compared with 2012 (higher number of farms with an average milk yield per cow per 305-d standard lactation of  $>8,000$  kg; 35.8% vs. 31.5%). The median number of cows per farm slightly increased from 20 (IQR 13 to 35) in 2012 to 22 (IQR 13 to 35) in 2022. Fleckvieh was the main breed (~73%) in both years. Descriptive numbers on general farm characteristics for both years are presented in Table 1. All these variables differed significantly ( $P < 0.001$ ), even after correction for multiple testing between the 2 examined years.

Data about farm distribution among the Austrian federal states in correlation with the numbers of farms registered with the Association of Austrian Cattle Breeders are provided in the supplemental materials (see Notes).

### Calving and Care of the Newborn

Numbers on calving management and care of the newborn calf among all the participating farms are presented in Table 2. A comparison of these data revealed significant differences for all the presented parameters ( $P < 0.001$ ). Consequently, subsampling was performed as described in Materials and Methods. The number of farms stating that the first colostrum was fed within 4 h after birth increased from 83.7% in 2012 to 87.2% in 2022. The percentage of farms offering first colostrum between 4 and 6 h decreased (13.6% vs. 2.2%). Offering first colostrum later than 6 h (1.1% vs. 5.2%), as well as farms where calves suckled their dam for first colostrum (1.6% vs. 3.2%), increased. Subsampling revealed that these changes were significant ( $P < 0.01$ ). If a calf did not ingest the colostrum, esophageal feeding was not performed on 63.1% (2012) and 64.0% (2022) of farms. Compared with 2012, the percentage of farms performing general esophageal feeding of colostrum decreased to 0.9% (6.0% in 2012), and the farms using this measure for calves that did not ingest the colostrum by teat increased from 27.1% in 2012 to 32.8% in 2022. These changes were significant ( $P < 0.01$  to 0.04) in the tested subsamples. Most of the farmers (71.9% and 69.0% in 2012 and 2022, respectively) offered 2 L to 4 L of colostrum to the calves within the first 6 h after birth. The percentage of farms offering less than 2 L increased from 13.3% in 2012 to 18.3% in 2022, resulting in a decrease in farms offering more than 4 L. This finding, however, was not significant when subsampling was applied. Overall, in 2012, 17.9% and in 2022, 26.7% of the farmers stated that they checked first colostrum quality. Most of these farms did this by visual inspection only. In 2012, an objective method (hydrometer) was used on 1.9% of

**Table 1.** Results of a survey about farm characteristics from dairy farms in Austria in the years 2012 and 2022<sup>1</sup>; all variables differed significantly between the examined years ( $P < 0.001$ )

| Variable                                                | Answer            | 2012 (%)    | 2022 (%)    |
|---------------------------------------------------------|-------------------|-------------|-------------|
| Predominant breed                                       | Fleckvieh         | 72.9        | 73.5        |
|                                                         | Brown Swiss       | 14.2        | 12.0        |
|                                                         | Holstein–Friesian | 7.5         | 7.0         |
|                                                         | Other             | 3.4         | 6.7         |
|                                                         | No answer         | 2.0         | 0.8         |
| Type of farm management                                 | Conventional      | 76.1        | 68.7        |
|                                                         | Organic           | 23.9        | 30.6        |
|                                                         | No answer         | 0           | 0.7         |
| Type of cow barn                                        | Freestall         | 56.4        | 62.1        |
|                                                         | Tiestall          | 42.8        | 36.9        |
|                                                         | No answer         | 0.8         | 1.0         |
| Access to pasture                                       | No                | 47.5        | 25.1        |
|                                                         | Yes               | 51.8        | 74.2        |
|                                                         | No answer         | 0.7         | 0.7         |
| Average milk yield per cow per 305-d standard lactation | <6,000 kg         | 13.1        | 8.3         |
|                                                         | 6,000–8,000 kg    | 54.6        | 49.5        |
|                                                         | 8,000–10,000 kg   | 28.9        | 30.9        |
|                                                         | >10,000 kg        | 2.7         | 4.9         |
|                                                         | No answer         | 0.7         | 6.4         |
| Number of cows (median; IQR in parentheses)             |                   | 20 (13; 30) | 22 (13; 35) |

<sup>1</sup>All variables are presented in percentages from the total number of participants of each year (2012:  $n = 1,287$  and 2022:  $n = 2,314$ ) except median (and percentiles) for the continuous variable number of cows, representing herd size.

farms, and in 2022, 9.4% used either a hydrometer, Brix refractometer, or outflow funnel to determine colostrum quality. Subsampling revealed that this 4.9-fold increase in the use of objective methods on farms was significant ( $P < 0.01$  to 0.04).

### Calf Housing

On most of the farms (88.8% and 86.6% in 2012 and 2022, respectively), calves were housed individually after birth. The percentage of farms housing the calves individually for only 1 to 2 weeks increased from 33.1% in 2012 to 38.6% in 2022, resulting in an overall shorter time of individual housing. These changes were significant when evaluating the raw data ( $P > 0.001$ ) but not significant when subsampling was performed ( $P > 0.10$ ). For details regarding calf housing, see Table 3.

### Calf Feeding

In both years, predominantly whole milk was fed (85.1% vs. 86.3%). The number of farms where non-salable or waste milk (defined as milk from cows with clinical mastitis, high somatic cell counts, or during treatment and within the withdrawal period after treatment with pharmaceuticals) was fed to all calves, only to male calves, or in exceptional cases decreased from 84.0% to 74.1% from 2012 to 2022. Changes were significant ( $P < 0.001$ ). These changes were also significant when subsampling was performed ( $P < 0.01$  to 0.04). In 2012, on 11.9% and in 2022, on 15.4% of the farms, milk

was offered ad libitum, and on 86.3% and 81.4%, milk fed was restricted. In the questionnaire, “ad libitum” was defined as, “the calves can drink as much as they want and have access to milk during the whole day (24 h).” We did not ask for the amount of milk offered or consumed. Subsampling revealed no significant difference in milk allowance between years ( $P = 0.13$  to 0.76). On most of the farms, calves were milk-fed via an artificial teat (75.4% vs. 84.4%). The number of farms using an automated milk feeder increased from 2.6% to 3.3%. In 2022, on most farms, weaning took place no earlier than wk 12 of life (64.9%). Especially, later weaning (>13 wk of life) increased by approximately 10% from 2012 to 2022 (16.4% vs. 26.0%). Subsampling for this later age at weaning revealed a significant difference between years ( $P < 0.01$  to 0.03). Further results regarding calf feeding and water provision are given in Table 4 and Figures 1 and 2).

### Calf Disease and Problems

Details on the estimated proportion of calves suffering from different diseases and problems are shown in Table 5. In 2012 and 2022, the most commonly recognized health issue in calves was diarrhea, followed by respiratory tract disease. Compared with 2012, in 2022, a higher percentage of farmers stated that they had a calf diarrhea incidence of above 10% ( $P < 0.001$ ). Changes regarding the occurrence of calf diarrhea were significant ( $P < 0.01$  to 0.02) with subsample testing. For other diseases, mortality, and cross-sucking, no sig-



**Table 2.** Answers given by 1,287 and 2,328 respondents in 2012 and 2022, respectively, on management at calving and care of the newborn calf on dairy farms in Austria; all variables differed significantly between the examined years ( $P < 0.001$ )

| Variable                                                                  | Answer                        | 2012 (%) | 2022 (%) |
|---------------------------------------------------------------------------|-------------------------------|----------|----------|
| Presence of a calving pen on farm                                         | No                            | 51.1     | 42.4     |
|                                                                           | Yes                           | 47.0     | 56.9     |
|                                                                           | No answer                     | 1.9      | 0.7      |
| Cow–calf separation p.n. <sup>1</sup>                                     | Immediately                   | 75.4     | 56.4     |
|                                                                           | Within 1 h                    | 13.4     | 17.6     |
|                                                                           | Within 4 h                    | 3.4      | 10.9     |
|                                                                           | Later than 4 h                | 7.9      | 13.1     |
|                                                                           | No answer                     | 0.2      | 2.0      |
| Time of first colostrum feeding p.n. <sup>1</sup>                         | Within 4 h                    | 83.7     | 87.2     |
|                                                                           | 4–6 h                         | 13.6     | 2.2      |
|                                                                           | >6 h                          | 1.1      | 5.2      |
|                                                                           | Calf suckles mother           | 1.6      | 3.2      |
|                                                                           | No answer                     | 0.2      | 2.2      |
| Quantity of first colostrum fed within the first 6 h p.n. <sup>1</sup>    | <2 L                          | 13.3     | 18.3     |
|                                                                           | 2–4 L                         | 71.9     | 69.0     |
|                                                                           | >4 L                          | 12.7     | 8.2      |
|                                                                           | Unknown, calf suckles mother  | 1.8      | 2.7      |
|                                                                           | No answer                     | 0.3      | 1.8      |
|                                                                           | No                            | 78.7     | 71.5     |
| Checking colostrum quality                                                | Yes                           | 20.8     | 26.7     |
|                                                                           | No answer                     | 0.5      | 1.8      |
|                                                                           | No                            | 78.7     | 71.5     |
| If checking colostrum was answered with “yes,” which method? <sup>2</sup> | Visual inspection             | 86.1     | 63.5     |
|                                                                           | Hydrometer                    | 9.4      | 8.8      |
|                                                                           | Brix refractometer            | 0.0      | 18.0     |
|                                                                           | Outflow funnel                | —        | 8.8      |
|                                                                           | No answer                     | 4.5      | 0.9      |
| Use of an esophageal feeder for first colostrum                           | No, not at all                | 63.1     | 64.0     |
|                                                                           | Yes, generally                | 6.0      | 0.9      |
|                                                                           | If necessary                  | 27.1     | 32.8     |
|                                                                           | No answer                     | 3.8      | 2.3      |
| Frozen colostrum stocks                                                   | No                            | 27.0     | 17.0     |
|                                                                           | Yes                           | 72.7     | 80.9     |
|                                                                           | No answer                     | 0.3      | 2.1      |
| Routine umbilical care                                                    | No measure                    | 27.0     | 31.7     |
|                                                                           | Dipping/spraying <sup>3</sup> | 19.7     | 24.7     |
|                                                                           | Stripping out                 | 12.1     | 10.4     |
|                                                                           | Combination                   | 37.6     | 29.4     |
|                                                                           | Other                         | 2.6      | 1.6      |
|                                                                           | No answer                     | 1.0      | 2.2      |

<sup>1</sup>p.n. = postnatum.<sup>2</sup>Percentage refers to all those who answered with “yes”: 2012, n = 267; 2022, n = 617.<sup>3</sup>Dipping and spraying with iodine, chlortetracycline, or foreshot (refers to the first portion of the distillate during the distillation process of schnapps).

nificant differences were observed when subsampling was performed.

### Preventive Measures

In 2012, we only asked for information about the mother cows' vaccination against pathogens causing diarrhea. This number doubled in 2022. In 2022, further measures were evaluated and are presented in Table 6.

## DISCUSSION

The response rate was similar between the 2 years, although the total number of respondents increased clearly. This was due to the fact that the questionnaire was distributed among dairy farms registered at the Association

of Austrian Cattle Breeders with an active email address, and this number has increased within the 10 years. This, nevertheless, may have influenced the outcome, as more modern and professional farms may have participated in a greater proportion. Furthermore, a potential bias may exist, as it cannot be excluded that particular farms, such as those with severe problems, tended not to participate.

Although the study was not designed as a representative survey, herd and farm characteristics (herd size, breed, milk yield, type of farm, and type of cows' barns) and regional distribution indicated that this survey gives a good overview of calf management practices of registered dairy breeders in Austria.

Further limitations of this work are that it was not possible to interview the same farms, as the questionnaire was anonymous. Unfortunately, we also have no

**Table 3.** Results on calf housing evaluated using an online survey among Austrian dairy farms in the years 2012 and 2022; the number of participants was 1,287 (2012) and 2,314 (2022) and all presented variables differed significantly ( $P < 0.001$ )

| Variable                                                  | Answer                              | 2012 (%) | 2022 (%) |
|-----------------------------------------------------------|-------------------------------------|----------|----------|
| Calves housed p.n. <sup>1</sup>                           | Individually                        | 88.8     | 86.6     |
|                                                           | Individually and in groups          | 6.3      | 2.6      |
|                                                           | In groups or with mother            | 4.7      | 8.7      |
|                                                           | No answer                           | 0.2      | 2.1      |
| Calf housing p.n. <sup>1</sup>                            | Within cows' barn                   | 46.0     | 45.1     |
|                                                           | Own barn for calves and young stock | 38.1     | 30.2     |
|                                                           | Outdoors                            | 15.5     | 7.0      |
|                                                           | Combination                         | —        | 15.3     |
| If calves are housed individually, how long? <sup>2</sup> | No answer                           | 0.4      | 2.4      |
|                                                           | 1–2 wk                              | 33.1     | 38.6     |
|                                                           | Up to 6 wk                          | 37.0     | 31.5     |
|                                                           | >6 wk                               | 23.2     | 16.2     |
| Cleaning of calf housing                                  | No answer                           | 6.7      | 13.7     |
|                                                           | Regularly                           | 61.1     | 82.5     |
|                                                           | Infrequently                        | 34.5     | 13.8     |
|                                                           | Not at all                          | 2.3      | 1.0      |
| Cleaning <sup>3</sup>                                     | No answer                           | 2.1      | 2.7      |
|                                                           | Only dry                            | 23.1     | 19.9     |
|                                                           | With water                          | 10.2     | 14.3     |
|                                                           | With high pressure                  | 42.2     | 68.1     |
|                                                           | Disinfection                        | 19.9     | 24.9     |

<sup>1</sup>p.n. = postnatum.<sup>2</sup>Percentage refers to all respondents who stated they house calves individually p.n.: 2012, n = 1,143; 2022, n = 2,004.<sup>3</sup>Multiple answers were allowed; sum of answers does not add up to 100%.

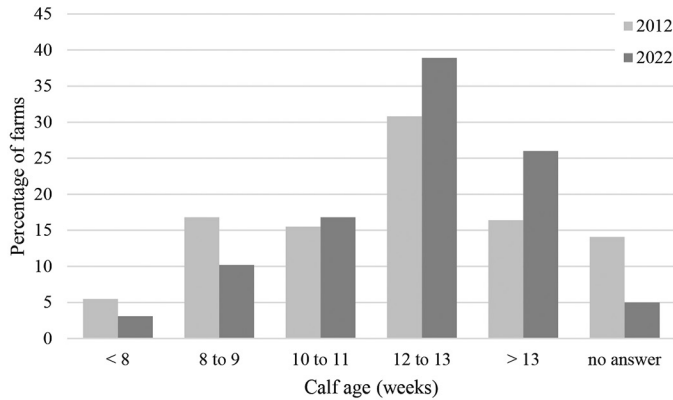
information on the participants about, for example, age, gender, education, and what kind of continuing education the participants attended, if any. Nevertheless, the aim of our study was to compare management on dairy farms in

Austria and see whether changes occurred and whether these are in accordance with recommendations from recent literature, without aiming to directly connect this to the information and education the farmers consumed

**Table 4.** Answers given during an online questionnaire by 1,287 respondents in 2012 and 2,328 respondents in 2022 on preweaning calf feeding on Austrian dairy farms; all variables differed significantly between the examined years ( $P < 0.001$ )

| Variable                                  | Answer                                       | 2012 (%) | 2022 (%) |
|-------------------------------------------|----------------------------------------------|----------|----------|
| Type of milk feed                         | Whole milk                                   | 85.1     | 86.3     |
|                                           | Milk replacer                                | 1.1      | 1.6      |
|                                           | Combination                                  | 13.0     | 9.0      |
|                                           | No answer                                    | 0.8      | 3.1      |
| Quantity of milk fed daily                | Restricted to 12% of calves' BW <sup>1</sup> | 58.3     | 56.2     |
|                                           | Restricted, >12% of calves' BW               | 28.0     | 25.2     |
|                                           | Ad libitum <sup>2</sup>                      | 11.9     | 15.4     |
|                                           | No answer                                    | 1.8      | 3.2      |
| Method of milk feeding                    | Bucket with artificial teat                  | 75.4     | 84.4     |
|                                           | Bucket without artificial teat               | 3.2      | 0.4      |
|                                           | Bucket with, then without artificial teat    | 16.8     | 8.4      |
|                                           | Automatic milk feeder                        | 2.6      | 3.3      |
|                                           | Other                                        | 0.7      | 0.6      |
|                                           | No answer                                    | 1.3      | 2.9      |
| Feeding waste milk <sup>3</sup> to calves | Not at all                                   | 14.8     | 24.8     |
|                                           | Yes, to all calves                           | 28.8     | 15.0     |
|                                           | Only to males                                | 30.9     | 38.0     |
|                                           | Only in exceptional cases                    | 24.4     | 19.1     |
|                                           | No answer                                    | 1.1      | 3.1      |

<sup>1</sup>For better understanding, an example was given to the farmers: "e.g., calf with BW 50 kg, maximum 6 L."<sup>2</sup>Defined for farmers as "Calves can drink as much as they want and always have access to milk."<sup>3</sup>Defined as milk from cows with clinical mastitis, high SCC, or during treatment and within the withdrawal period after treatment with drugs.

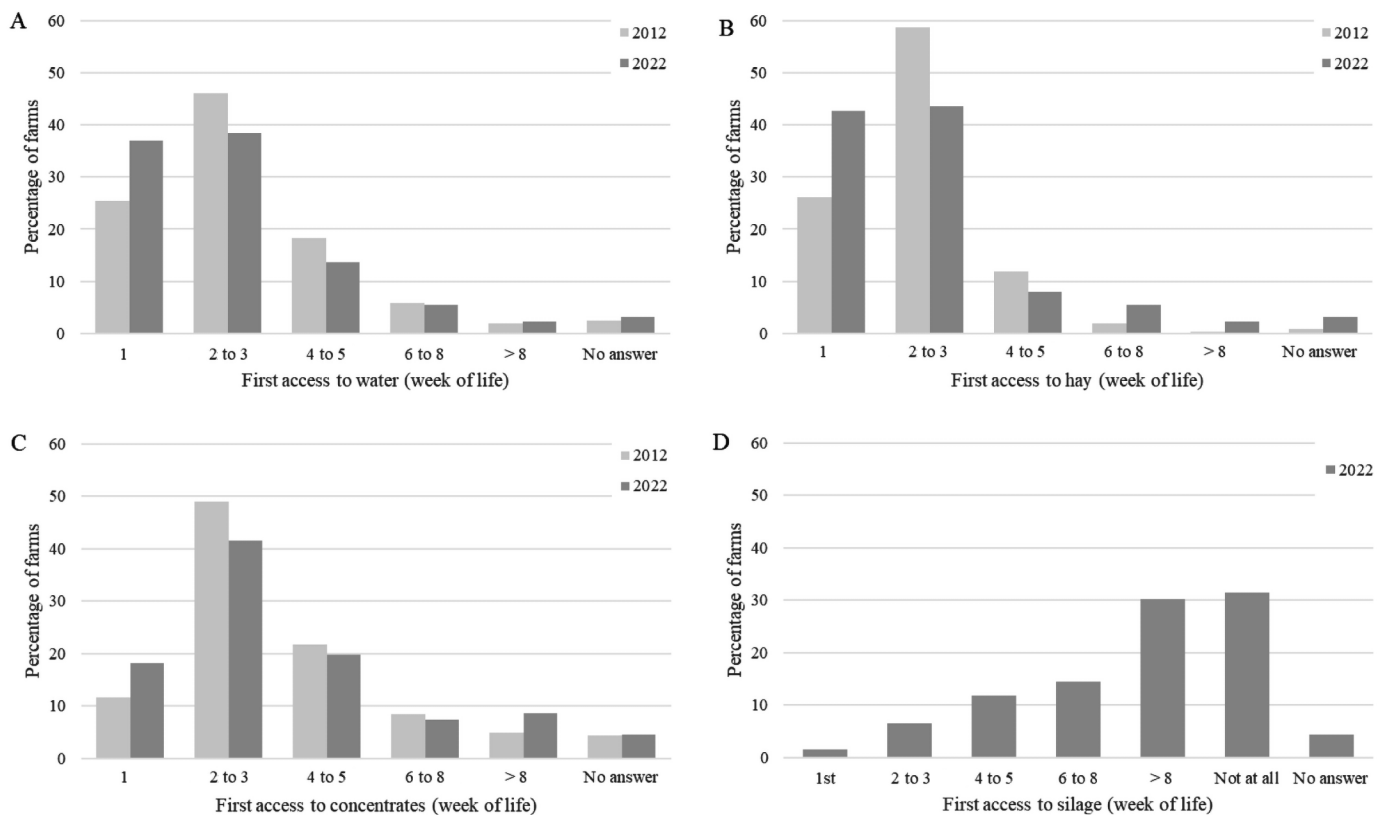


**Figure 1.** Results of weaning age of calves (wk) from an online survey among Austrian dairy farms in 2012 (n = 1,287) and 2022 (n = 2,328). These data differed significantly ( $P < 0.001$ ).

during this time. Another important limitation of this type of survey is the risk that answers do not reflect true practices, because the answers are influenced by social acceptability and legislation. Legislation affecting calf management might have caused differences between the years 2012 and 2022; however, it has not been changed.

In 2012, we identified areas that could be improved on farms when practices were compared with recommendations from recent literature. These topics were colostrum management, especially testing for colostrum quality, social housing of calves, and milk feeding strategies.

An adequate transfer of passive immunity is important for newborn calves (Lombard et al., 2020; Robbers et al., 2021). Generally, fast provision of colostrum to the newborn is essential. Furthermore, calves should receive colostrum in an adequate quantity and quality (Robbers et al., 2021; Lopez and Heinrichs, 2022). Most of surveyed the farmers seem to be aware of the importance of timely colostrum feeding in newborns. Interestingly, the results revealed a tendency to feed lower amounts of first colostrum. The reasons for this are unknown. Another risk factor for failure of passive transfer is low colostrum quality ( $< 50$  g of immunoglobulin G per liter; Lombard et al., 2020). A high variance in the IgG concentration from cow to cow, also within the herd, is possible (Bartens et al., 2016; Kessler et al., 2020; Westhoff et al., 2024). Consequently, it is recommended that colostrum quality be tested on the farm to make management decisions. It has, however, to be taken into account that indirect



**Figure 2.** Data from online questionnaires on Austrian dairy farms in the years 2012 and 2022: age in weeks when calves on farm usually have first access to (A) water, (B) hay, (C) concentrate, and (D) silage. Data from 2012 (n = 1,287) and 2022 (n = 2,328) are shown, except for (D) silage, as this was not asked in 2012. All variables differed significantly between the examined years ( $P < 0.001$ ).

**Table 5.** Results of a survey on calf disease from dairy farms in Austria in the years 2012 and 2022; all variables differed significantly between the examined years ( $P < 0.001$ )<sup>1</sup>

| Disease/problem             | Year | Reported incidence (%) |       |       |       |     | No answer |
|-----------------------------|------|------------------------|-------|-------|-------|-----|-----------|
|                             |      | <10                    | 11–25 | 26–50 | 51–75 | >75 |           |
| Diarrhea                    | 2012 | 51.0                   | 23.4  | 9.8   | 4.0   | 2.6 | 9.2       |
|                             | 2022 | 36.6                   | 32.4  | 19.7  | 4.8   | 2.9 | 3.6       |
| Respiratory tract disease   | 2012 | 54.7                   | 6.4   | 1.9   | 0.5   | 0.2 | 36.3      |
|                             | 2022 | 75.2                   | 14.6  | 3.8   | 0.7   | 0   | 5.7       |
| Umbilical disease           | 2012 | 57.0                   | 3.5   | 0.5   | 0.1   | 0   | 38.9      |
|                             | 2022 | 86.2                   | 5.1   | 1.2   | 0.1   | 0   | 7.4       |
| Joint problems              | 2012 | 47.1                   | 1.3   | 0.1   | 0.1   | 0   | 51.4      |
|                             | 2022 | 86.7                   | 1.9   | 0     | 0     | 0   | 11.4      |
| Calf mortality <sup>2</sup> | 2012 | 58.0                   | 3.2   | 0.2   | 0     | 0.1 | 38.6      |
|                             | 2022 | 89.0                   | 4.3   | 0.3   | 0     | 0   | 6.4       |
| Cross-sucking               | 2012 | 31.8                   | 19.4  | 11.0  | 4.0   | 0.6 | 33.2      |
|                             | 2022 | 49.6                   | 22.5  | 16.2  | 3.9   | 2.7 | 5.1       |

<sup>1</sup>All variables are presented as percentages from the total number of participants of each year: 2012, n = 1,287; 2022, n = 2,314. The age of the calves affected was not defined in the questionnaire.

<sup>2</sup>Defined as calves born alive that died within the first 3 wk of life.

on-farm methods highly correlate with immunoglobulin concentration in colostrum but have limits with regard to their sensitivity and specificity. On-farm test methods are the use of a hydrometer or colostrometer, Brix refractometer, outflow funnel, and lateral flow assays (Ahmann et al., 2021; Röder et al., 2023). The results of our questionnaires revealed that the number of farms stating to test colostrum quality using an on-farm test increased 4.9-fold. Nevertheless, approximately 90% of the farms still do not do this. Although the outlet funnel was not tested scientifically before 2022, approximately one-quarter of all respondents stated they would use this method. In a recently published study by Röder et al. (2023), the outlet funnel was not accurate enough to distinguish between good-quality and low-quality colostrum. The advice, often presented as the “Three Q’s” (quick, quantity, and quality; Robbers et al., 2021), is clear. Apart from the need for early colostrum provision, most of the participating farmers did not perform colostrum management in

accordance with this advice. Another interesting finding regarding the importance of an early transfer of passive immunity was that most of the farmers declined to feed colostrum via an esophageal tube, even if the calf did not ingest any colostrum via teat. Measures to improve colostrum management are relatively easy to perform, not time consuming, and not cost intensive. The reason farmers do not perform colostrum management following these guidelines is unclear. This raises the question of how to transfer the knowledge from research to the farmers and how to convince them to implement these measures in their daily routines.

To address animal welfare, it is necessary to take the natural behavior of calves into account (Whalin et al., 2021). In this context, social housing and feeding are regularly studied. Several studies have shown the positive effects of social housing, such as pair housing of newborn calves (Costa et al., 2016; Abdelfattah et al., 2018; Whalin et al., 2018, 2021; Knauer et al., 2021). In

**Table 6.** Results on prophylactic measures with regard to calf health evaluated during an online questionnaire among dairy farmers in Austria in the years 2012 and 2022<sup>1</sup>

| Variable                                                             | Option                    | 2012 (%) | 2022 (%) |
|----------------------------------------------------------------------|---------------------------|----------|----------|
| Cow vaccination against diarrhea                                     |                           | 4.5      | 9.6      |
| Cow vaccinations against respiratory tract diseases                  |                           |          | 1.0      |
| Calf vaccinations against respiratory tract diseases                 |                           |          | 3.1      |
| Routine use of halofuginone lactate to control for cryptosporidiosis |                           |          | 9.3      |
| Iron supplementation to calves                                       |                           |          | 13.1     |
| If iron was supplemented, how? <sup>2</sup>                          | Once/injection            |          | 65.7     |
|                                                                      | Via milk or milk replacer |          | 31.8     |
|                                                                      | Both                      |          | 2.5      |
| Selenium supplementation (to dry cows or newborn calves)             |                           |          | 42.5     |

<sup>1</sup>The 2012 survey only asked for “vaccination against calf diarrhea” (n = 1,287). The answers to this question differed significantly between the years ( $P < 0.001$ ). In 2022, additional questions were asked and presented (n = 2,328).

<sup>2</sup>Percentage refers to all those who stated they supplement iron (n = 304).



our study, the majority of farmers stated that they house calves individually after birth. One reason for the high number of farms performing individual housing could be the relatively small herd size. This leads to the problem that farms often do not have 2 calves of the same or comparable age that could be paired or grouped from the start of their lives. However, findings from North America, where farms are larger, were similar (Roche et al., 2023). As a possible reason for this finding, Roche et al. (2023) stated that studies regarding health and disease in grouped calves differed, although these effects could be influenced by other factors, such as colostrum management (Bučková et al., 2021) or nutrition (Umaña Sedó et al., 2023). The fear of pathogen transmission was also presented as a reason for limiting the contact between calves in an English survey (Mahendran et al., 2022) and might be another reason for the low number of farmers in our study stating that they keep calves paired or grouped. This, however, was unfortunately not asked. Furthermore, avoiding cross-sucking could be a reason for the decision to house calves individually (Costa et al., 2016). This could also be true for the farms in the present study, as this behavior has been recognized regularly on farms of our study.

For decades, milk allowance for dairy calves was restricted to encourage calves to ingest concentrates early and to allow smooth weaning at an early age (Drackley, 2008; Khan et al., 2011). Meanwhile, advice has changed, adopting more of the physiological and natural feeding behavior of young calves by recommending increased or ad libitum milk feeding in the first weeks of calves' lives (Lorenz, 2021). Several studies are available showing the positive effect of such a milk feeding strategy on calves' development, growth, health, and immune system (Hammon et al., 2018; Lorenz et al., 2021; Bahmanpour et al., 2023; Ockenden et al., 2023). When reviewing the information provided to farmers in Austria, calf feeding was the most frequently presented topic (Slamanig, 2022). Overall, 9 journal articles and 8 presentations explicitly focused on ad libitum milk feeding. When comparing the results of the online questionnaires from 2012 and 2022, only slight differences were found, but they were not significant after subsampling. To encourage farmers to increase milk feeding levels, a better understanding of the reasons why they do not do so is necessary, but farmers were not asked to explain or justify their feeding regimen in this questionnaire. One often-discussed possible negative effect of an intensified milk feeding strategy is delayed or decreased solid feed intake and delayed and impaired rumen development (Drackley, 2008; Khan et al., 2016). This, however, has not been proven (Schäff et al., 2018).

With regard to more natural behavior and calf feeding, weaning age also has to be taken into account (Whalin

et al., 2021; Welk et al., 2024). In our questionnaires, weaning age increased significantly between the years. In 2022, 65% of the participants stated that calves were not weaned before wk 12 of their lives. This outcome was, however, influenced by organic-producing farms, where legislation requires calves to be milk-fed until wk 12 of life. However, in 60.0% of the conventional farms, calves were not weaned before wk 12.

Calf mortality rates reflect health and welfare (Umaña Sedó et al., 2023). In our survey, the median calf mortality rate (defined as calves born alive that died within 21 d of life) was 3% (IQR 1% to 5%) in 2022. As definitions of calf mortality vary, it is challenging to compare data and apply target numbers (Umaña Sedó et al., 2023). Often-stated targets for preweaning calf mortality rates range between <3% and <5%. The mortality rates given by the surveyed farmers and their estimations of the occurrence of calf diseases, especially the increased calf diarrhea incidence in 2022, do not indicate successful calf management on these farms. Data on disease incidence have to be interpreted with care, as they may represent perception rather than true numbers, and we did not define the age of calves for this question. An increase in perception of diarrhea could also be possible, as a higher milk allowance may cause more liquid feces. However, farms that stated a lower incidence of diarrhea significantly ( $P < 0.001$ ) more often fed higher amounts of milk than farms with incidences of >10%. Furthermore, the reported incidence of diarrhea increased far more steeply than the number of farms offering higher amounts of milk. Consequently, we suggest that this could only explain some of these findings. Risk factors for disease and mortality in calves include inadequate transfer of passive immunity, suboptimal housing, and suboptimal energy provision (Whalin et al., 2018; Johnsen et al., 2021; Lorenz et al., 2021; Sutter et al., 2023). In our study, weak points regarding calf management were not offering enough colostrum, not testing for colostrum quality, neglecting to house calves socially post natum, and feeding restricted amounts of milk.

Unfortunately, we did not include questions on continuing education in our questionnaire. This means we do not know whether the participants attended any offered lectures or trainings or read articles on calf management. Knowledge, however, does not guarantee implementation, as shown, for example, for colostrum management (Palczynski et al., 2020). The reason why farmers do not follow these general recommendations is unclear. This leaves the question of how to close the gap between information, knowledge, and translation of knowledge into practice (More, 2009; Hoischen-Taubner et al., 2018). One key point is the perception of problems and diseases, and this may be highly heterogeneous between groups, such as farmers, veterinarians, researchers, and

consultants, as well as within a group of stakeholders (Pakenham-Walsh, 2004; Liyanage et al., 2009; Lam et al., 2013). It would also be interesting to know whether information and advice from different advisers (e.g., veterinarians, advisers from different industries or government) vary and may consequently lead to confusion, as well as to learn whom the farmers trust the most. This could be the topic of a future survey, to help improve advice and knowledge transfer. Furthermore, different tools for knowledge transfer may be required for different people and target groups.

## CONCLUSIONS

In this follow-up study, we detected some changes in calf management practices between the surveyed years of 2012 and 2022 but still found potential for improvement. Weak points were especially detected in the areas of colostrum management, milk and milk replacer feeding, and social housing. Although information for farmers regarding these areas is numerous and distributed via different channels (e.g., journals, continuing education training), there is still a lack of implementation of measures on the farms. Further research should focus on methods and tools to bridge this gap between knowledge and implementation.

## NOTES

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**Nonstandard abbreviations used:** IQR = interquartile range.

## REFERENCES

- Abdelfattah, E. M., M. M. Karousa, D. C. Lay Jr., J. N. Marchant-Forde, and S. D. Eicher. 2018. Short communication: Effect of age at group housing on behavior, cortisol, health, and leukocyte differential counts of neonatal bull dairy calves. *J. Dairy Sci.* 101:596–602. <https://doi.org/10.3168/jds.2017-12632>.
- Ahmman, J., J. Steinhoff-Wagner, and W. Büscher. 2021. Determining immunoglobulin content of bovine colostrum and factors affecting the outcome: A review. *Animals (Basel)* 11:3587. <https://doi.org/10.3390/ani11123587>.
- Bahmanpour, A. S., F. Fatahnia, M. Mirzaei, G. Taasoli, H. Mirzaei-Alamoti, and H. R. Jafari. 2023. Milk plane of nutrition and alfalfa hay provision in neonatal Holstein calves: Growth performance, ruminal fermentation characteristics, and blood biochemical attributes. *Anim. Feed Sci. Technol.* 299:115636. <https://doi.org/10.1016/j.anifeedsci.2023.115636>.
- Bartens, M. C., M. Drillich, K. Rychli, M. Iwersen, T. Arnholdt, L. Meyer, and D. Klein-Jöbstl. 2016. Assessment of different methods to estimate bovine colostrum quality on farm. *N. Z. Vet. J.* 64:263–267. <https://doi.org/10.1080/00480169.2016.1184109>.
- Beaver, A., K. L. Proudfoot, and M. A. G. von Keyserlingk. 2020. Symposium review: Considerations for the future of dairy cattle housing: An animal welfare perspective. *J. Dairy Sci.* 103:5746–5758. <https://doi.org/10.3168/jds.2019-17804>.
- Bučková, K., R. Šárová, Á. Moravcsíková, and M. Špinka. 2021. The effect of pair housing on dairy calf health, performance, and behavior. *J. Dairy Sci.* 104:10282–10290. <https://doi.org/10.3168/jds.2020-19968>.
- Costa, J. H. C., M. A. G. von Keyserlingk, and D. M. Weary. 2016. Invited review: Effects of group housing of dairy calves on behavior, cognition, performance, and health. *J. Dairy Sci.* 99:2453–2467. <https://doi.org/10.3168/jds.2015-10144>.
- Drackley, J. K. 2008. Calf nutrition from birth to breeding. *Vet. Clin. North Am. Food Anim. Pract.* 24:55–86. <https://doi.org/10.1016/j.cvfa.2008.01.001>.
- Grothe, J., and R. M. Thornsberry. 2022. Commercial dairy calf management: Impact on performance and health. *Vet. Clin. North Am. Food Anim. Pract.* 38:63–75. <https://doi.org/10.1016/j.cvfa.2021.11.005>.
- Hammon, H. M., D. Fritten, C. Gerbert, C. Koch, G. Dusel, R. Weikard, and C. Kühn. 2018. Different milk diets have substantial effects on the jejunal mucosal immune system of pre-weaning calves, as demonstrated by whole transcriptome sequencing. *Sci. Rep.* 8:1693. <https://doi.org/10.1038/s41598-018-19954-2>.
- Hoischen-Taubner, S., A. Bielecke, and A. Sundrum. 2018. Knowledge transfer regarding the issue of animal health. *Org. Agric.* 8:105–120. <https://doi.org/10.1007/s13165-017-0175-9>.
- Johnsen, J. F., I. H. Holmøy, A. Nødtvedt, and C. M. Mejdell. 2021. A survey of pre-weaning calf management in Norwegian dairy herds. *Acta Vet. Scand.* 63:20. <https://doi.org/10.1186/s13028-021-00587-x>.
- Kessler, E. C., R. M. Bruckmaier, and J. J. Gross. 2020. Colostrum composition and immunoglobulin G content in dairy and dual-purpose cattle breeds. *J. Anim. Sci.* 98:skaa237. <https://doi.org/10.1093/jas/skaa237>.
- Khan, M. A., A. Bach, D. M. Weary, and M. A. G. von Keyserlingk. 2016. Invited review: Transitioning from milk to solid feed in dairy heifers. *J. Dairy Sci.* 99:885–902. <https://doi.org/10.3168/jds.2015-9975>.
- Khan, M. A., D. M. Weary, and M. A. G. Von Keyserlingk. 2011. Invited review: Effects of milk ration on solid feed intake, weaning, and performance in dairy heifers. *J. Dairy Sci.* 94:1071–1081. <https://doi.org/10.3168/jds.2010-3733>.
- Klein-Jöbstl, D., T. Arnholdt, F. Sturmlechner, M. Iwersen, and M. Drillich. 2015. Results of an online questionnaire to survey calf management practices on dairy cattle breeding farms in Austria and to estimate differences in disease incidences depending on farm structure and management practices. *Acta Vet. Scand.* 57:44. <https://doi.org/10.1186/s13028-015-0134-y>.
- Knauer, W. A., S. M. Godden, A. K. Rendahl, M. I. Endres, and B. A. Crooker. 2021. The effect of individual versus pair housing of dairy heifer calves during the preweaning period on measures of health, performance, and behavior up to 16 weeks of age. *J. Dairy Sci.* 104:3495–3507. <https://doi.org/10.3168/jds.2020-18928>.
- Lam, T. J., B. H. van den Borne, J. Jansen, K. Huijps, J. C. van Veersen, G. van Schaik, and H. Hogeveen. 2013. Improving bovine udder health: A national mastitis control program in the Netherlands. *J. Dairy Sci.* 96:1301–1311. <https://doi.org/10.3168/jds.2012-5958>.
- Liyanage, C., T. Elhag, T. Ballal, and Q. Li. 2009. Knowledge communication and translation—A knowledge transfer model. *J. Knowl. Manage.* 13:118–131. <https://doi.org/10.1108/13673270910962914>.
- Lombard, J., N. Urie, F. Garry, S. Godden, J. Quigley, T. Earleywine, S. McGuirk, D. Moore, M. Branan, M. Chamorro, G. Smith, C. Shively,

- D. Catherman, D. Haines, A. J. Heinrichs, R. James, J. Maas, and K. Sterner. 2020. Consensus recommendations on calf- and herd-level passive immunity in dairy calves in the United States. *J. Dairy Sci.* 103:7611–7624. <https://doi.org/10.3168/jds.2019-17955>.
- Lopez, A. J., and A. J. Heinrichs. 2022. Invited review: The importance of colostrum in the newborn dairy calf. *J. Dairy Sci.* 105:2733–2749. <https://doi.org/10.3168/jds.2020-20114>.
- Lorenz, I. 2021. Calf health from birth to weaning—An update. *Ir. Vet. J.* 74:5. <https://doi.org/10.1186/s13620-021-00185-3>.
- Lorenz, I., R. Huber, and F. M. Trefz. 2021. A high plane of nutrition is associated with a lower risk for neonatal calf diarrhea on Bavarian dairy farms. *Animals (Basel)* 11:3251. <https://doi.org/10.3390/ani11113251>.
- Mahendran, S. A., D. C. Wathes, R. E. Booth, and N. Blackie. 2022. A survey of calf management practices and farmer perceptions of calf housing in UK dairy herds. *J. Dairy Sci.* 105:409–423. <https://doi.org/10.3168/jds.2021-20638>.
- More, S. 2009. Global trends in milk quality: Implications for the Irish dairy industry. *Ir. Vet. J.* 62(Suppl. 4):S5–S14. <https://doi.org/10.1186/2046-0481-62-S4-S5>.
- Nawroth, C., and M. V. Rørvang. 2022. Opportunities (and challenges) in dairy cattle cognition research: A key area needed to design future high welfare housing systems. *Appl. Anim. Behav. Sci.* 255:105727. <https://doi.org/10.1016/j.applanim.2022.105727>.
- Ockenden, E. M., V. M. Russo, B. J. Leury, K. Giri, and W. J. Wales. 2023. Prewaning nutrition and its effects on the growth, immune competence and metabolic characteristics of the dairy calf. *Animals (Basel)* 13:829. <https://doi.org/10.3390/ani13050829>.
- Pakenham-Walsh, N. 2004. Learning from one another to bridge the “know-do gap”. *BMJ* 329:1189. <https://doi.org/10.1136/bmj.329.7475.1189>.
- Palczynski, L. J., E. C. L. Bleach, M. L. Brennan, and P. A. Robinson. 2020. Giving calves ‘the best start’: Perceptions of colostrum management on dairy farms in England. *Anim. Welf.* 29:45–58. <https://doi.org/10.7120/09627286.29.1.045>.
- Robbers, L., R. Jorritsma, M. Nielen, and A. Koets. 2021. A scoping review of on-farm colostrum management practices for optimal transfer of immunity in dairy calves. *Front. Vet. Sci.* 8:668639. <https://doi.org/10.3389/fvets.2021.668639>.
- Roche, S., D. L. Renaud, C. A. Bauman, J. Lombard, D. Short, J. Saraceni, and D. F. Kelton. 2023. Calf management and welfare in the Canadian and US dairy industries: Where do we go from here? *J. Dairy Sci.* 106:4266–4274. <https://doi.org/10.3168/jds.2022-22793>.
- Röder, M., S. Borchardt, W. Heuwieser, E. Rauch, R. Sargent, and F. Sutter. 2023. Evaluation of laboratory and on-farm tests to estimate colostrum quality for dairy cows. *J. Dairy Sci.* 106:9164–9173. <https://doi.org/10.3168/jds.2023-23467>.
- Schäff, C. T., J. Gruse, J. Maciej, R. Pfuhl, R. Zitnan, M. Rajskey, and H. M. Hammon. 2018. Effects of feeding unlimited amounts of milk replacer for the first 5 weeks of age on rumen and small intestinal growth and development in dairy calves. *J. Dairy Sci.* 101:783–793. <https://doi.org/10.3168/jds.2017-13247>.
- Serdar, C. C., M. Cihan, D. Yucel, and M. A. Serdar. 2021. Sample size, power and effect size revisited: Simplified and practical approaches in pre-clinical, clinical and laboratory studies. *Biochem. Med. (Zagreb)* 31:010502. <https://doi.org/10.11613/BM.2021.010502>.
- Sirovica, L. V., C. Ritter, J. Hendricks, D. M. Weary, S. Gulati, and M. A. G. von Keyserlingk. 2022. Public attitude toward and perceptions of dairy cattle welfare in cow-calf management systems differing in type of social and maternal contact. *J. Dairy Sci.* 105:3248–3268. <https://doi.org/10.3168/jds.2021-21344>.
- Slamanig, F. 2022. Knowledge transfer from research to farm/Wissenstransfer von Themen des Kälbermanagements von der Forschung zur Landwirtin/zum Landwirt. Veterinary Medicine Diploma thesis. Clinical Unit for Herd Health Management in Ruminants, University Clinic for Ruminants, Department for Farm Animals and Veterinary Public Health, University of Veterinary Medicine, Vienna, Austria.
- Sutter, F., P. L. Venjakob, W. Heuwieser, and S. Borchardt. 2023. Association between transfer of passive immunity, health, and performance of female dairy calves from birth to weaning. *J. Dairy Sci.* 106:7043–7055. <https://doi.org/10.3168/jds.2022-22448>.
- Umaña Sedó, S. G. U., C. B. Winder, and D. L. Renaud. 2023. Graduate student literature review: The problem of calf mortality in dairy farms. *J. Dairy Sci.* 106:7164–7176. <https://doi.org/10.3168/jds.2022-22795>.
- Welk, A., H. W. Neave, and M. B. Jensen. 2024. Invited review: The effect of weaning practices on dairy calf performance, behavior, and health—A systematic review. *J. Dairy Sci.* 107:5237–5258. <https://doi.org/10.3168/jds.2024-24521>.
- Westhoff, T. A., S. Borchardt, and S. Mann. 2024. Invited review: Nutritional and management factors that influence colostrum production and composition in dairy cows. *J. Dairy Sci.* 107:4109–4128. <https://doi.org/10.3168/jds.2023-24349>.
- Whalin, L., D. M. Weary, and M. A. G. von Keyserlingk. 2018. Short communication: Pair housing dairy calves in modified calf hutches. *J. Dairy Sci.* 101:5428–5433. <https://doi.org/10.3168/jds.2017-14361>.
- Whalin, L., D. M. Weary, and M. A. G. von Keyserlingk. 2021. Understanding behavioural development of calves in natural settings to inform calf management. *Animals (Basel)* 11:2446. <https://doi.org/10.3390/ani11082446>.
- Wickham, H., R. François, L. Henry, K. Müller, and D. Vaughan. 2023a. dplyr: A Grammar of Data Manipulation. Accessed Apr. 19, 2023. <https://github.com/tidyverse/dplyr>, <https://dplyr.tidyverse.org>.
- Wickham, H., and L. Henry. 2023. purrr: Functional Programming Tools. Accessed Apr. 19, 2023. <https://github.com/tidyverse/purrr>, <https://purrr.tidyverse.org/>.
- Wickham, H., D. Vaughan, and M. Girlich. 2023b. tidyr: Tidy Messy Data. Accessed Apr. 19, 2023. <https://github.com/tidyverse/tidyr>, <https://tidyr.tidyverse.org>.

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