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Differences in growth performance and disease incidence between bull and heifer calves and between calves born to primiparous and multiparous cows during the pre-weaning period

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ABSTRACT. A dataset was constructed from seven studies on Holstein calves and used to characterise differences between male and female calves, and between calves born to primiparous and multiparous cows in terms of transfer of passive immunity, feed intake, growth performance and disease incidence during the first 60 days of life. Birth body weight (BW), BW at 60 days of age, and average daily gain (ADG) were higher in bull calves compared to heifer calves. Starter intake and feed efficiency were also greater in bull calves, whereas the duration of diarrhoea was shorter. Calves born to multiparous cows had a higher birth BW than those born to primiparous cows. The difference of BW was maintained until 60 days of age, however, ADG, feed intake and feed efficiency did not differ between calves born to primiparous and multiparous cows. Neither calf sex nor dam parity affected the incidence of diarrhoea, the frequency of health treatments, or the odds of developing diarrhoea and requiring health treatment.

KEY WORDS: calves, lactation number, performance, sex

Introduction

The dairy industry focuses predominantly on rearing heifer calves because females are essential for maintaining dairy herds. However, bull calves are commonly used in studies aimed at optimising calf-rearing protocols, and the results are often extrapolated to heifer calves. This practice is likely based on the assumption that physiological and growth differences between males and females during the first weeks of life are absent or negligible. This notion is reflected in many studies by the omission of calf sex from the statistical model, the lack of reporting or discussion of sex-related differences when sex was included in the analysis, or speculation about potential differences between bull and heifer calves rather than conclusions supported by scientific evidence (Kehoe et al., 2008; Jaeger et al., 2020; Beiranvand et al., 2022; Rahimi et al., 2023). However, in numerous studies that included both bull and heifer calves, and accounted for calf sex in the statistical analysis, sex significantly affected at least some of the measured parameters (Baumgard et al., 2002; Garcia et al., 2015; Ware et al., 2015; Górka et al., 2023). Nevertheless, the findings have been inconsistent. For example, average daily gain (ADG) differed between bull and heifer calves in some studies (Akayezu et al., 1994; Górka et al., 2023; Mushtaq et al., 2024), whereas no such differences were observed in others (Mirzaei et al., 2018; Górka et al., 2021; Jafarpour et al., 2023).

Of many factors that may contribute to the inconsistent findings between individual studies, insufficient statistical power is likely one of the most important, as many studies included relatively few animals per treatment group (Mirzaei et al., 2018; Jafarpour et al., 2023). Furthermore, potential sex-related differences in susceptibility to diseases, including diarrhoea, have rarely been investigated, even in the available reviews (Andersen and Plum, 1965; Holland and Odde, 1992), likely due to difficulties in detecting differences in these outcomes when studies involve only a limited number of animals. Consequently, a large-scale study or pooled dataset analysis should be carried out to accurately characterise differences between bull and heifer calves in growth, feed intake, feed efficiency, and especially disease incidence. Such information would facilitate the interpretation and extrapolation of findings from studies conducted in one sex to the other.

Besides the sex of calves, dam parity may also influence the performance of newborn calves (Hoseyni et al., 2016; Shivley et al., 2018). Previous studies have shown that dam parity affects disease incidence during the first weeks of life, as well as subsequent milk production and reproductive performance of the offspring (González-Recio et al., 2012; Carvalho et al., 2020). However, until recently, only a limited number of studies have accounted for dam parity at parturition while allocating claves to treatments (Hoseyni et al., 2016; Shivley et al., 2018; Stefańska et al., 2021; Gąsiorek et al., 2022), despite the well-established influence of dam parity on calf BW (Andersen and Plum, 1965; Hoseyni et al., 2016; Carvalho et al., 2020). Therefore, the magnitude of expected differences in growth, feed intake, feed efficiency and other rearing parameters between calves born to primiparous and multiparous cows has not been comprehensively characterised in dairy breeds.

The aim of this study was to assess the effects of calf sex and dam parity (primiparous vs. multiparous) on growth performance and selected health parameters during the pre-weaning period in Holstein cattle. We hypothesised that growth performance and disease incidence during the pre-weaning period would differ substantially between bull and heifer calves, as well as between calves born to primiparous and multiparous cows.

Material and methods

Background information

The present study was a retrospective observational analysis using datasets from seven studies conducted on Holstein calves. Five datasets originated from previously published studies [one study from Górka et al. (2021) and four studies from Górka et al. (2023)], whereas two datasets were obtained from unpublished trials. The pooled dataset included records of passive immunity, BW, ADG, feed intake, feed efficiency (gain-to-feed ratio), and pre-weaning disease incidence for 588 calves (289 bulls and 299 heifers), including 206 calves born to primiparous cows and 382 calves born to multiparous cows. Only records with complete data were included in the analysis. Of the initial 592 records, data from four calves were excluded because they died during the study. The experimental procedures in each study complied with Polish legislation implementing EU Directive 2010/63/EU on the protection of animals used for scientific purposes. The studies were conducted under routine farm conditions and involved no invasive procedures beyond routine management. Blood samples were collected as part of the standard operating procedures for newborn calves at each farm, and the resulting data were made available for the purposes of the present study (detailed below). Therefore, formal ethical approval was not required.

Animals, feeding and housing

The studies were conducted on two commercial dairy farms [Gospodarstwo Rolno-Hodowlane Żydowo Sp. z o.o., Żydowo, Poland (five studies: three published and two unpublished) and Hodowla Zwierząt Zarodowych Osowa Sień Sp. z o.o., Przyczyna Górna, Poland (two published studies)]. In all studies, calves were assigned to one of three or four treatments (16 to 25 calves per treatment) at 10 days of age, either randomly or using a randomized block design. The treatments differed in the feed additive, or combination of feed additives included in the milk replacer (MR), or in the ingredient composition of the MR. Consequently, the original datasets covered the period from 10 to 60 days of age (Górka et al., 2021; Górka et al., 2023). However, birth BW was routinely recorded by the farms as part of their standard management procedures, and these data were obtained for the present analysis. Therefore, the observation period was extended to cover the entire pre-weaning period, from birth to 60 days of age. In all studies, calves from difficult calvings, twin or triplet births, or calves showing signs of disease or poor condition were excluded before treatment allocation (Górka et al., 2021; Górka et al., 2023). Animals were assigned to treatments by the scientist coordinating each study, and the calf was the experimental unit.

Housing and feeding of calves were similar in all studies and followed the procedures described by Górka et al. (2021) and Górka et al. (2023). Calves were separated from the dam directly after birth and housed individually in hutches [150 × 120 × 125 cm (length × width × hight)] with an additional outside area (150 × 120 cm), for the entire study period. Hutches were placed on concrete, bedded with straw, and arranged to prevent physical contact between calves.

In all studies, the experimental MR was introduced on day 10 of age. Calves were routinely weighed at birth, and subsequently on days 10 (start of MR feeding) and 60 of age (end of the study), as well as every 10 to 25 days between days 10 and 60, depending on the study. Body weight was measured using electronic scales calibrated weekly. During the first 10 days of life, calves received first colostrum followed by either a mixture of colostrum and transition milk, or a mixture of colostrum and MR, depending on the study. All calves received 4 l of first colostrum via a stomach tube within 2 h after birth, regardless of birth BW or calf sex. In five studies, only high-quality maternal colostrum [≥23 BRIX; ≥50 g IgG/l; Godden et al. (2019)] was fed, whereas frozen colostrum (also ≥23 BRIX) was used when maternal colostrum did not meet the quality criteria. In the remaining two studies, colostrum quality in terms of IgG concentration was not controlled, and frozen colostrum was used only when maternal colostrum showed signs of mastitis.

In all studies, from day 10 to 60 of age, calves were fed 900 g of MR powder daily provided in 6 l of MR solution (150 g of MR powder in 1 l), divided into three equal feedings (3 × 2 l). From day 10 of age, calves were fed a starter mixture offered *ad libitum*. Although the composition of the MR and starter differed between some studies, feeding management was otherwise similar across all studies (Górka et al., 2021; Górka et al., 2023). Milk replacer and starter intake was monitored in all studies, and feed samples were collected and analysed as described by Górka et al. (2021) and Górka et al. (2023), allowing feed efficiency to be calculated between days 10 to 60 of calves age. Specifically, MR intake was recorded daily, whereas cumulative starter intake was determined using the procedure described by Górka et al. (2021). Briefly, starter was replenished as it was consumed, and the amount offered gradually increased with growing intake, allowing cumulative starter intake over the study period to be calculated. Water was available *ad libitum*. Thus, colostrum feeding and also MR and starter feeding between day 10 to 60 of age was very similar in all studies.

In all studies, treatments were balanced for the number of bull and heifer calves at the time of allocation. However, dam parity (primiparous or multiparous) was not considered during treatment allocation, although a similar proportion of calves born to primiparous and multiparous cows was targeted in each treatment. Consequently, the effect of dam parity was not evaluated in any study included in the pooled dataset. Animal health was monitored daily by farm personnel as part of the routine management of newborn calves. Faecal score was used as an indicator of diarrhoea. Depending on the study, faecal consistency was scored using either a 3-point (Abdelfattah et al., 2024) or 4-point scale (Larson et al., 1977), and diarrhoea was defined as a faecal score ≥2 or ≥3. A new diarrhoea episode was recorded only if it was preceded by at least one day with normal faeces (faecal score 1 or ≤2, depending on the scoring system used). Respiratory disease was diagnosed using the Wisconsin Calf Health Scoring Chart (McGuirk and Peek, 2014). Similarly, subsequent episodes of respiratory disease or health treatment were recorded only if they were preceded by at least one day without clinical signs or treatment. Animals were evaluated individually, and all health issues were reported to the attending veterinarian, who decided whether treatment was required or, if necessary, whether the calf should be removed from the study.

Data and data processing

For the purpose of the present study, transfer of passive immunity, birth BW, BW at days 10 and 60 of age, ADG from birth to 60 of age, feed intake and apparent feed efficiency [g ADG/kg dry matter (DM) intake from MR and starter] between days 10 and 60 of age, and the frequency and duration of abnormal faeces and frequency of health treatments between days 10 and 60 were analysed. Feed intake and disease incidence before day 10 were not analysed because calves entered the studies at 10 days of age, and these data were not consistently recorded across all datasets. Because faecal consistency was assessed using either a 3-point or a 4-point scale, resulting in methodological inconsistency between studies, faecal score itself was not included in the statistical analysis. Abnormal faeces were defined, depending on the study, as a faecal score ≥2 or ≥3. Transfer of passive immunity was routinely assessed on each farm by the attending veterinarian as part of herd management and colostrum-feeding monitoring, and these data were subsequently made available for the purposes of the present study. Passive immunity was determined using total serum protein (TSP) measured in serum samples collected between 3 and 6 days of age with a refractometer (Reichert VET 360, Reichert Technologies, New York, USA). For the purpose of the current study, faultier of passive transfer was defined as TSP < 5.1 (Lombard et al., 2020).

Statistical analysis

Based on the conducted power analysis, the number of records included in the current study (~300 calves of each sex and >200 calves born to primiparous or multiparous cows) allowed to detect differences in birth BW and BW at 60 days of age of 1.5 and 2.0 kg, respectively, with a statistical power of 0.80 and a significance level of $\alpha = 0.05$, assuming standard deviation (SD) values of 5.0 and 8.5 kg for birth BW and BW at 60 days of age, respectively. Power analysis was performed using PROC POWER in SAS (version 9.4).

Before statistical analysis, data were examined for normality and outliers using PROC UNIVARIATE in SAS (version 9.4). Based on this analysis, two outliers were removed, resulting in a final dataset of 586 calves (287 bulls and 299 heifers and 206 calves born to primiparous and 380 calves born to multiparous cows).

Results for passive immunity, BW, ADG, MR intake, and feed efficiency were analysed using the MIXED procedure in SAS (version 9.4). The statistical model included the fixed effect of calf sex, dam parity (primiparous or multiparous), and their interaction, together with the random effects of calf, farm and study nested within farm. Because starter intake was not normally distributed and data transformation did not correct the distribution, starter intake was analysed using ROC NPAR1WAY with the WILCOXON option to test the significance of the main effects. Subsequently, PROC RANK was used to rank the response variable, and a two-way ANOVA was performed on the ranked data using PROC GLM; means and the corresponding standard error of the mean are presented in tables. Starter intake was also analysed using the same model with initial BW included as a covariate to determine whether any differences between bull and heifer calves or calves born to primiparous or multiparous cows could be explained by differences in initial BW difference. The frequency and duration of abnormal faeces and the frequency of respiratory disease and health treatments (antibiotics, anti-inflammatory drugs, or both) were analysed using PROC GENMOD with a Poisson distribution. In addition to the effects described above, TSP was included in the model as a covariate to verify whether any potential differences between bull and heifer calves or calves born to primiparous or multiparous cows could be explained by differences in transfer of passive immunity. Odds ratios for failure of passive transfer, abnormal faeces, respiratory disease, and health treatment were estimated by logistic regression using PROC GLIMMIX with a binomial distribution. When a significant interaction was detected, least-squares means were compared using the PDIFF option with Tukey adjustment. Mortality was not analysed because only a few calves died during the studies. Unless otherwise stated, results are presented as least-squares means and the corresponding standard error or standard error of the mean. Statistical significance was declared at $P < 0.05$, and a tendency was declared when $0.05 \leq P \leq 0.10$.

Results

Birth BW and BW at 10 and 60 days of age were higher for bull calves compared to heifer calves ($P < 0.01$; Table 1). Bull calves had also higher ADG ($P = 0.02$), feed efficiency ($P = 0.02$) and starter intake ($P = 0.01$) than heifer calves. Starter intake remained higher in bull calves also when initial BW was included in the statistical model as a covariate ($P = 0.01$), despite the significant effect of initial BW ($P < 0.01$), indicating that the difference in starter intake between bull and heifer calves could not be attributed to higher BW of the former. Calves born to multiparous cows had higher birth BW and BW at 10 and 60 days of age compared to calves born to primiparous cows ($P < 0.01$); however, ADG, feed intake and feed efficiency did not differ between the two groups ($P \geq 0.71$).

Duration of abnormal faeces was shorter in bull than in heifer calves ($P < 0.01$) and frequency of abnormal faeces tended to ($P = 0.06$) be lower in bulls. The shorter duration of abnormal faeces in bull calves remained significant when TSP was included in the statistical model as a covariate ($P = 0.05$), whereas the tendency for a lower frequency of abnormal faeces was no longer evident ($P = 0.18$). Neither the duration nor the frequency of abnormal faeces was affected by dam parity ($P \geq 0.31$). The frequency of respiratory disease and health treatments, as well as the odds of failure of passive transfer, abnormal faeces, respiratory disease, and health treatment, were not affected by calf sex or dam parity ($P \geq 0.20$; Table 1 and 2). Although a significant interaction between calf sex and dam parity was detected for the frequency of respiratory disease ($P = 0.05$), pairwise comparisons did not identify significant differences among the subclasses.

Discussion

The results of the present study support our hypothesis that growth performance differs between bull and heifer calves, as well as between calves born to primiparous and multiparous cows. In particular, the current findings indicate that results obtained in studies conducted exclusively on bull calves, a common practice, particularly in studies involving invasive experimental procedures or euthanasia at the end of the study, should be extrapolated to heifer calves with caution. In contrast, no substantial differences were observed in health outcomes between bull and heifer calves or between calves born to primiparous and multiparous cows, except for shorter duration of abnormal faeces in bull calves.

Higher BW of bull calves is consistent with previous studies (Akayezu et al., 1994; Kertz et al., 1997; Garcia et al., 2015) and a review by Andersen and Plum (1965). However, the difference observed in the present study was smaller, averaging only 2–3 kg for both birth BW and BW at 60 days of age, compared to the 4–5 kg or greater differences in earlier studies. Considering that the SD of birth BW and BW at 60 days of age in the present dataset was 5 and 8.5 kg, respectively, and that similar SD of birth BW was reported in other studies in Holstein calves (Kertz et al., 1997; Burakowska et al., 2021), more than 100 calves per treatment group would be required to detect a 2–3 kg difference in BW between bull and heifer calves with a statistical power of 0.8 at $\alpha = 0.05$. This may explain why many studies with relatively small sample sizes failed to detect differences in BW between bull and heifer calves unless those differences were relatively large (i.e. ≥4–5 kg BW). The same limitation may also have reduced the ability to detect differences in ADG, feed intake and feed efficiency between calves of different sexes in those studies.

While the higher birth BW of Holstein male calves compared to female calves is well established (Andersen and Plum, 1965; Holland and Odde, 1992), potential sex-related differences in ADG, feed intake, and feed efficiency during the pre-weaning period have received much less attention. Consistent with previous works (Akayezu et al., 1994; Garcia et al., 2015; Ware et al., 2015), bull calves in the present study had higher ADG and feed efficiency pre-weaning than heifer calves. Together with their greater birth BW, which is known to influence BW later in life (Swail and Wathes, 2006; Hurst et al., 2021), these differences contributed to the higher BW of bull calves at 60 days of age.

Higher ADG of bull calves was, at least in part, a result of their higher starter intake, which was offered *ad libitum*, and thus was likely the main factor contributing to differences in ADG between calves receiving the same volumes of liquid feed (Greenwood et al., 1997). However, the greater starter intake of bull calves may have resulted from their lower MR intake relative to BW, because the volume of MR offered was fixed for all animals and the inverse relationship between MR intake and starter intake has been consistently reported in newborn calves (Quigley et al., 2006; Chapelain et al., 2025). However, the higher starter intake of bull calves remained significant after adjusting for initial BW, suggesting that it was associated primarily with calf sex rather than differences in body size. Previous studies have reported inconsistent results regarding sex-related differences in starter intake before weaning. Bull calves consumed more starter in some studies (Górka et al., 2023), whereas the opposite was observed in others (Greenwood et al., 1997; Górka et al., 2021; Górka et al., 2023). The present study indicate that bull calves generally consume more starter than heifer calves, and also utilize feed more efficiently. Nevertheless, detected differences were modest (628 vs. 609 g/day for ADG and 588 vs. 572 g ADG/kg DM for feed efficiency) and were therefore likely difficult to detect in studies with smaller sample sizes. Despite being statistically significant, they also reflect the considerable variation between animals and studies. It should also be noted that some studies reported sex-related differences between bull and heifer calves mainly after weaning (Korst et al., 2017).

Greater birth BW of Holstein calves born to multiparous cows is consistent with the results of other authors (Andersen and Plum, 1965; Holland and Odde, 1992; Kertz et al., 1997; Hoseyni et al., 2016; Carvalho et al., 2020). In the current study, this difference persisted until day 60 of age, while ADG, feed intake and feed efficiency did not differ between calves born to primiparous and multiparous cows. These findings suggest that despite differences in birth BW, postnatal growth is not influenced by dam parity. Similar results were reported by Hoseyni et al. (2016). However, in a survey study, calves born to multiparous cows had higher ADG compared to calves born to heifers, which was attributed to the lower birth BW of the latter, and, thus, lower growth potential (Shivley et al., 2018). Considering that BW was carefully monitored in all the studies included in the present analysis and the study by Hoseyni et al. (2016), because growth performance was a primary objective, unlike in the survey study of Shivley et al. (2018), the present findings support the conclusion that, in general, ADG and feed efficiency do not differ between calves born to primiparous and multiparous cows. Hence, the difference in weaning BW can be largely explained by the difference in birth BW.

It is worth noting that some authors have reported an interaction between dam parity and calf sex with respect to ADG. Specifically, only bull calves born to primiparous cows had higher ADG than heifer calves (Ware et al., 2015). The reason for this interaction is difficult to explain and was not confirmed in the present analysis. Similarly, no interaction between dam parity and calf sex has been reported in beef cattle, where calves suckle their dams and growth depends largely on the dam's milk yield (Bair et al., 1972).

The lack of an effect of calf sex and dam parity on the frequency of abnormal faeces and health treatments, as well as on the odds of developing abnormal faeces or requiring health treatment, is particularly noteworthy, as the majority of studies conducted to date have been underpowered to detect differences in disease incidence between bull and heifer calves and between calves born to primiparous versus multiparous cows. However, Carvalho et al. (2020), in a study conducted on a large number of calves from a single dairy herd, reported that disease incidence differed between calves born to primiparous and multiparous cows.

Despite the fact that disease incidence was not affected by calf sex, the duration of abnormal faeces was shorter in bull than heifer calves. This was observed despite similar transfer of passive immunity in both males and females. Furthermore, the effect was still significant when TSP was included in the statistical model as a covariate, indicating that colostrum intake was unlikely to be the primary factor contributing to this difference. Because each day with diarrhoea may reduce ADG and feed efficiency in calves (Shivley et al., 2018), the shorter duration of abnormal faeces in bull calves may also have contributed to their greater ADG and feed efficiency. In line with previous reports (Soberon et al., 2012; Shivley et al., 2018; Abuelo et al., 2021; Cavirani et al., 2023), calves diagnosed with abnormal faeces or requiring health treatment had lower ADG in the current study (626 vs. 656 g/day; $P = 0.02$; data not shown).

Numerous differences observed between bull and heifer calves, as well as between calves born to primiparous and multiparous cows, may arise during foetal development. In Holstein cattle, gestation length is generally 1–1.5 days longer for male than female calves (Dhakal et al., 2013; Tomasek et al., 2017). The same is true for multiparous cows, which generally have longer gestation lengths (Dhakal et al., 2013). Besides resulting in greater birth BW (Mwangi et al., 2025), longer gestation may also better prepare newborn calves for extrauterine life, as foetal growth is most intensive during the last days of gestation (Prior and Laster, 1979). On the other hand, prolonged gestation is associated with greater birth BW and an increased risk of dystocia (Mwangi et al., 2025). Dystocia and difficult calvings may negatively affect calf vitality, colostrum intake, passive immunity transfer, and early-life health status (Lombard et al., 2007; Mee, 2008). However, calves from difficult calvings were not included in the studies analysed here. Consequently, the effects of calf sex and dam parity were not confounded by potential differences in the distribution of calves born from difficult calvings among the analysed groups. Furthermore, incidence of diseases, particularly susceptibility to diarrhoea, may depend on the health status of the cow during pregnancy (Carvalho et al., 2020), which was unfortunately not monitored in the current study. Furthermore, the shorter duration of abnormal faeces in bull calves may be associated with differences in gastrointestinal microbiota composition observed during the first weeks of life (Milik et al., 2023; Rojas et al., 2024). However, it is worth noting that bull and heifer calves had similar TSP despite all calves receiving the same volume of colostrum. Given their greater BW at birth, bull calves likely absorbed immunoglobulins more efficiently. However, this could simply result from the lower amount of colostrum consumed relative to BW, as the efficiency of immunoglobulin absorption decreases with rising colostrum intake (Frederick et al., 2025).

While interpreting the results of this study, it should also be taken into account that, on the farms where studies were conducted, bull and heifer calves were managed in a similar manner. Because male calves are not the primary source of income on dairy farms, they are often managed differently from heifer calves. In many cases, bulls are kept under poorer housing conditions than heifers, and their feeding management differs from that of female calves. Research has shown that providing high-quality colostrum to bull calves is not a priority on many dairy farms, as the highest-quality colostrum is often reserved for heifers. In addition, the amount of milk or MR offered to bull calves is frequently lower, and animals intended for sale within the first days of life may not receive starter feed (Renaud et al., 2017; Renaud et al., 2020a; Renaud et al., 2020b). This was not the case in the present analysis, which should be taken into account when interpreting the results.

Conclusions

In summary, compared to Holstein heifer calves, bull calves of this breed can be expected to have higher birth BW, ADG, starter intake, and feed efficiency during the first weeks of life, resulting in greater weaning BW. Calf sex does not exert any substantial impact on the odds of developing abnormal faeces or requiring health treatment, although bull calves can be expected to have a shorter duration of abnormal faeces. Apart from lower birth BW and, consequently, lower weaning BW in calves born to primiparous cows, no substantial differences can be expected between Holstein calves born to primiparous and multiparous cows.

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Conflict of interest

The Authors declare that there is no conflict of interest.

References

Abdelfattah E.M., Aly S.S., Lehenbauer T.W., Karle B.M., 2024. Effects of simplified group housing on behavior, welfare, growth performance, and health of preweaned dairy calves on a California dairy. J. Dairy Sci. 107, 3927–3940, https://doi.org/10.3168/jds.2023-23820

Abuelo A., Cullens F., Brester J.L., 2021. Effect of preweaning disease on the reproductive performance and first-lactation milk production of heifers in a large dairy herd. J. Dairy Sci. 104, 7008–7017, https://doi.org/10.3168/jds.2020-19791

Akayezu J.M., Linn J.O., Otterby D.E., Hansen W.P., 1994. Evaluation of calf starters containing different amounts of crude protein for growth of holstein calves. J. Dairy Sci. 77, 1882–1889, https://doi.org/10.3168/jds.S0022-0302(94)77130-7

Andersen H., Plum M., 1965. Gestation length and birth weight in cattle and buffaloes: a review. J. Dairy Sci. 48, 1224–1235, https://doi.org/10.3168/jds.S0022-0302(65)88431-4

Bair L.G., Wilson L.L., Ziegler J.H., 1972. Effects of calf sex and age of dam on pre- and post-weaning performance of calves from an angus-holstein crossbred herd. J. Anim. Sci. 35, 1155–1159, https://doi.org/10.2527/jas1972.3561155x

Baumgard L.H., Weber W.J., Kazmer G.W., Zinn S.A., Hansen L.B., Chester-Jones H., Crooker B.A., 2002. Effects of selection for milk yield on growth hormone response to growth hormone Releasing factor in growing Holstein calves. J. Dairy Sci. 85, 2529–2540, https://doi.org/10.3168/jds.S0022-0302(02)74336-1

Beiranvand H., Ahmadi F., Tahmasbi R., Farokhzad M.R., Ariana M., Ghaffari M.H., 2022. Performance of Holstein calves receiving equal solids per day from high-solids milk and milk replacer blend once or twice daily combined with dry versus wet fine-particle starter diet. JDS Commun. 3, 317–321, https://doi.org/10.3168/jdsc.2021-0194

Burakowska K., Penner G.B., Korytkowski Ł., Flaga J., Kowalski Z.M., Górka P., 2021. Canola meal or soybean meal as protein source and the effect of microencapsulated sodium butyrate supplementation in calf starter mixture. I. Performance, digestibility, and selected blood variables. J. Dairy Sci. 104, 6646–6662, https://doi.org/10.3168/jds.2020-19779

Carvalho M.R., Aboujaoude C., Penagaricano F., Santos J.E.P., DeVries T.J., McBride B.W., Ribeiro E.S., 2020. Associations between maternal characteristics and health, survival, and performance of dairy heifers from birth through first lactation. J. Dairy Sci. 103, 823–839, https://doi.org/10.3168/jds.2019-17083

Cavirani S., Cabassi C., Spadini C., Schiano E., Pietro M., Federico R., Bassi G., Taddei S., 2023. From a healthy calf to a performing cow: a case-control study. Large Anim. Rev. 29, 47–50

Chapelain T., Wilms J.N., Martín-Tereso J., Leal L.N., Daniel J.B., 2025. Performance, nutrient digestibilities, and metabolic profiles of Holstein calves fed whole milk or milk replacer at two feeding levels. J. Dairy Sci. 108, 2422–2444, https://doi.org/10.3168/jds.2024-25556

Dhakal K., Maltecca C., Cassady J.P., Baloche G., Williams C.M., Washburn S.P., 2013. Calf birth weight, gestation length, calving ease, and neonatal calf mortality in Holstein, Jersey, and crossbred cows in a pasture system. J. Dairy Sci. 96, 690–698, https://doi.org/10.3168/jds.2012-5817

Frederick G., Wieland M., Singh A., Ewing R., Steele M.A., Somula H., Mann S., 2025. Effects of feeding colostrum volume at 6%, 8%, 10%, or 12% of birth body weight on efficiency of immunoglobulin G absorption, gastric emptying, and postfeeding behavior in Holstein calves. J. Dairy Sci. 108, 13680–13690, https://doi.org/10.3168/jds.2025-27228

Garcia M., Shin J.H., Schlaefli A., Greco L.F., Maunsell F.P., Santos J.E.P., Staples C.R., Thatcher W.W., 2015. Increasing intake of essential fatty acids from milk replacer benefits performance, immune responses, and health of preweaned Holstein calves. J. Dairy Sci. 98, 458–477, https://dx.doi.org/10.3168/jds.2014-8384

Godden S.M., Lombard J.E., Woolums A.R., 2019. Colostrum management for dairy calves. Vet. Clin. North. Am. Food Anim. Pract. 35, 535–556, https://doi.org/10.1016/j.cvfa.2019.07.005

González-Recio O., Ugarte E., Bach A., 2012. Trans-generational effect of maternal lactation during pregnancy: a Holstein cow model. PLOS One 7, e51816, https://doi.org/10.1371/journal.pone.0051816

Górka P., Budzińska K., Budziński W., Jankowiak T., Kehoe S., Kański J., 2021. Effect of probiotic and nucleotide supplementation in milk replacer on growth performance and fecal bacteria in calves. Livest. Sci. 250, 104556, https://doi.org/10.1016/j.livsci.2021.104556

Górka P., Milik J., Budziński W., Przybyło M., Kański J., Jankowiak T., Budzińska K., 2023. Effect of sodium butyrate, phytogenic compounds and egg yolk antibodies supplementation in calf milk replacer containing probiotic bacteria on farms feeding a mixture of surplus colostrum and transition milk to calves in their first days of life. Anim. Feed Sci. Technol. 302, 115675, https://doi.org/10.1016/j.anifeedsci.2023.115675

Greenwood R.H., Morrill J.L., Titgemeyer E.C., 1997. Using dry feed intake as a percentage of initial body weight as a weaning criterion. J. Dairy Sci. 80, 2542–2546, https://doi.org/10.3168/jds.S0022-0302(97)76208-8

Holland M.D., Odde K.G., 1992. Factors affecting calf birth weight: A review. Theriogenol. 38, 769–798, https://doi.org/10.1016/0093-691X(92)90155-K

Hoseyni F., Mahjoubi E., Zahmatkesh D., Yazdi M.H., 2016. Effects of dam parity and pre-weaning average daily gain of Holstein calves on future milk production. J. Dairy Res. 83, 453–455, https://doi.org/10.1017/S0022029916000558

Hurst T.S., Lopez-Villalobos N., Boerman J.P., 2021. Predictive equations for early-life indicators of future body weight in Holstein dairy heifers. J. Dairy Sci. 104, 736–749, https://doi.org/10.3168/jds.2020-18560

Jaeger B.M., Ziegler D., Schimek D., Ziegler B., Chester-Jones H., Casper D.P., 2020. Growth performance of newborn dairy calves fed a milk replacer containing 24% crude protein and 20% fat fed at different feeding rates. App. Anim. Sci. 36, 208–218, https://doi.org/10.15232/aas.2019-01867

Jafarpour M., Alikhani M., Riasi A., Omidi-Mirzaei H., Khorvash M., Ghaffari M.H., 2023. Effects of corn grain processing and protein source on calf performance, rumen fermentation, and blood metabolites. Sci. Rep. 13, 10129, https://doi.org/10.1038/s41598-023-37365-w

Kehoe S.I., Heinrichs A.J., Baumrucker C.R., Greger D.L., 2008. Effects of nucleotide supplementation in milk replacer on small intestinal absorptive capacity in dairy calves. J. Dairy Sci. 91, 2759–2770, https://doi.org/10.3168/jds.2007-0751

Kertz A.F., Reutzel L.F., Barton B.A., Ely R.L., 1997. Body weight, body condition score, and wither height of prepartum Holstein cows and birth weight and sex of calves by parity: a database and summary. J. Dairy Sci. 80, 525–529, https://doi.org/10.3168/jds.S0022-0302(97)75966-6

Korst M., Koch C., Kesser J., Muller U., Romberg F.J., Rehage J., Eder K., Sauerwein H., 2017. Different milk feeding intensities during the first 4 weeks of rearing in dairy calves: Part 1: Effects on performance and production from birth over the first lactation. J. Dairy Sci. 100, 3096–3108, https://doi.org/10.3168/jds.2016-11594

Larson L.L., Owen F.G., Albright J.L., Appleman R.D., Lamb R.C., Muller L.D., 1977. Guidelines toward more uniformity in measuring and reporting calf experimental data. J. Dairy Sci. 60, 989–991, https://doi.org/10.3168/jds.S0022-0302(77)83975-1

Lombard J., Urie N., Garry F., Godden S., Quigley J., Earleywine T., McGuirk S., Moore D., Branan M., Chamorro M., Smith G., Shivley C., Catherman D., Haines D., Heinrichs A.J., James R., Maas J.et al.Sterner K., 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

Lombard J.E., Garry F.B., Tomlinson S.M., Garber L.P., 2007. Impacts of dystocia on gealth and survival of dairy calves. J. Dairy Sci. 90, 1751–1760, https://doi.org/10.3168/jds.2006-295

McGuirk S.M., Peek S.F., 2014. Timely diagnosis of dairy calf respiratory disease using a standardized scoring system. Anim. Health Res. Rev. 15, 145–147, https://doi.org/10.1017/S1466252314000267

Mee J.F., 2008. Prevalence and risk factors for dystocia in dairy cattle: A review. Vet. J. 176, 93–101, https://doi.org/10.1016/j.tvjl.2007.12.032

Milik J., Górka P., Budzińska K., Kański J., Jankowiak T., 2023. Effect of supplementing sodium butyrate, phytogenic compounds and egg yolk antibodies in calf milk replacer containing probiotic bacteria on selected faecal bacteria in calves. J. Anim. Feed Sci. 32, 438–446, https://doi.org/10.22358/jafs/166154/2023

Mirzaei M., Dadkhah N., Baghbanzadeh-Nobari B., Agha-Tehrani A., Eshraghi M., Imani M., Shiasi-Sardoabi R., Ghaffari M.H., 2018. Effects of preweaning total plane of milk intake and weaning age on intake, growth performance, and blood metabolites of dairy calves. J. Dairy Sci. 101, 4212–4220, https://doi.org/10.3168/jds.2017-13766

Mushtaq S.H., Hussain D., Hifz Ul R., Naveed-Ul-Haque M., Ahmad N., Sardar A.A., Chishti G.A., 2024. Effect of once-a-day milk feeding on behavior and growth performance of pre-weaning calves. Anim. Biosci. 37, 253–260, https://doi.org/10.5713/ab.23.0073

Mwangi S.I., Buckley F., Ilatsia E.D., Berry D.P., 2025. Gestation length and its associations with calf birth weight, calf perinatal mortality, and dystocia in dairy cattle. J. Dairy Sci. 108, 8685–8696, https://doi.org/10.3168/jds.2024-26044

Prior R.L., Laster D.B., 1979. Development of the bovine fetus. J. Anim. Sci. 48, 1546–1553, https://doi.org/10.2527/jas1979.4861546x

Quigley J.D., Wolfe T.A., Elsasser T.H., 2006. Effects of additional milk replacer feeding on calf health, growth, and selected blood metabolites in calves. J. Dairy Sci. 89, 207–216, https://doi.org/10.3168/jds.S0022-0302(06)72085-9

Rahimi A., Ghorbani G.R., Hashemzadeh F., Mirzaei M., Saberipour H.R., Ahmadi F., Ghaffari M.H., 2023. Impact of corn processing and weaning age on calf performance, blood metabolites, rumen fermentation, and behavior. Sci. Rep. 13, 10701, https://doi.org/10.1038/s41598-023-37728-3

Renaud D.L., Duffield T.F., LeBlanc S.J., Haley D.B., Kelton D.F., 2017. Management practices for male calves on Canadian dairy farms. J. Dairy Sci. 100, 6862–6871, https://doi.org/10.3168/jds.2017-12750

Renaud D.L., Steele M.A., Genore R., Roche S.M., Winder C.B., 2020a. Passive immunity and colostrum management practices on Ontario dairy farms and auction facilities: A cross-sectional study. J. Dairy Sci. 103, 8369–8377, https://doi.org/10.3168/jds.2020-18572

Renaud D.L., Waalderbos K.M., Beavers L., Duffield Z.T.F., Leslie K.E., Windeyer M.C., 2020b. Risk factors associated with failed transfer of passive immunity in male and female dairy calves: A 2008 retrospective cross-sectional study. J. Dairy Sci. 103, 3521–3528, https://doi.org/10.3168/jds.2019-17397

Rojas D., Estrada R., Romero Y., Figueroa D., Quilcate C., Ganoza-Roncal J.J., Maicelo J.L., Coila P., Alvarado W., Cayo-Colca I.S., 2024. Sex-induced changes in microbial eukaryotes and prokaryotes in gastrointestinal tract of simmental cattle. Biology (Basel) 13, 932, https://doi.org/10.3390/biology13110932

Shivley C.B., Lombard J.E., Urie N.J., Haines D.M., Sargent R., Kopral C.A., Earleywine T.J., Olson J.D., Garry F.B., 2018. Preweaned heifer management on US dairy operations: Part II. Factors associated with colostrum quality and passive transfer status of dairy heifer calves. J. Dairy Sci. 101, 9185–9198, https://doi.org/10.3168/jds.2017-14008

Soberon F., Raffrenato E., Everett R.W., Van Amburgh M.E., 2012. Preweaning milk replacer intake and effects on long-term productivity of dairy calves. J. Dairy Sci. 95, 783–793, https://doi.org/10.3168/jds.2011-4391

Swail A., Wathes D.C., 2006. Influence of the dam and sire on size at birth and subsequent growth, milk production and fertility in dairy heifers. Theriogenology 66, 1173–1184, https://doi.org/10.1016/j.theriogenology.2006.03.028

Tomasek R., Rezac P., Havlicek Z., 2017. Environmental and animal factors associated with gestation length in Holstein cows and heifers in two herds in the Czech Republic. Theriogenology 87, 100–107, https://doi.org/10.1016/j.theriogenology.2016.08.009

Ware J.V., Franklin S.T., Jackson J., McAllister A.J., Cassell B.G., 2015. Genetic and environmental effects on early growth and performance in purebred Holstein, Jersey, and reciprocal crossbred calves. J. Dairy Sci. 98, 1255–1260, https://doi.org/10.3168/jds.2014-8056

Table 1. Passive immune status at the initiation of the study (TSP), BW, ADG, feed intake, feed efficiency, and faecal score of calves

	Calf characteristic[1]				SE	Main effects		
	Bull		Heifer			Sex	Dam	Sex × dam
	Primi	Multi	Primi	Multi				
n	82	205	124	175				
TSP, g/l	5.84	5.74	5.79	5.69	0.155	0.33	0.07	0.94
BW, kg								
day 1	40.6	42.0	38.4	40.7	1.05	<0.01	<0.01	0.15
day 10	44.1	45.0	41.8	43.9	1.05	<0.01	<0.01	0.07
day 60	78.7[ab]	79.1[a]	74.5[c]	77.4[b]	3.77	<0.01	<0.01	0.03
ADG, g/day	636	621	605	613	48.5	0.02	0.71	0.15
Milk replacer intake, kg DM[2]	43.5	43.5	43.4	43.5	1.00	0.48	0.90	0.47
Starter intake, kg DM[2]	16.9	16.3	14.9	15.5	0.29	0.01	0.61	0.32
Feed efficiency, g ADG /kg DM[3]	590	585	567	577	45.0	0.02	0.73	0.27
Abnormal faeces								
duration, days[3]	1.21	1.40	1.60	1.59	0.094	<0.01	0.31	0.24
frequency, n/calf[3]	0.56	0.69	0.80	0.74	0.074	0.06	0.57	0.20
Respiratory disease frequency, n/calf[3]	0.10	0.06	0.07	0.12	0.023	0.50	0.89	0.05
Health treatment[4] frequency, n/calf[3]	0.49	0.46	0.50	0.58	0.058	0.23	0.74	0.32

BW – body weight, ADG – average daily gain, DM – dry matter, TSP – total serum protein, SE – standard error of the mean, n – number animals in the group; [1] bull or heifer calf born from a primi- (Primi) or multiparous (Multi) cow; [2] cumulative intake from day 10 until day 60 of age; [3] from day 10 until day 60 of age; [4] treatment with antibiotic, anti-inflammatory drug or both; [abc] – values with different superscripts differ significantly (*P* < 0.05)

Table 2. Odds rations for failure of passive transfer (TSP < 5.1 g/dl), developing abnormal faeces, respiratory disease and health treatment in calves

Variable and comparison[1]	Coefficient	SEM	OR	95% CI	*P*-value
Failure of passive transfer					
Bull vs. Heifers	−0.1396	0.23	0.87	0.56, 1.36	0.54
Primi vs. Multi	−0.2145	0.24	0.81	0.59, 1.30	0.38
Abnormal faeces					
Bull vs. Heifers	−0.2321	0.18	0.79	0.55, 1.32	0.20
Primi vs. Multi	0.0507	0.19	1.05	0.73, 1.53	0.79
Respiratory disease					
Bull vs. Heifers	−0.2172	0.29	0.81	0.46, 1.42	0.45
Primi vs. Multi	0.0073	0.30	1.01	0.56, 1.82	0.98
Health treatment[2]					
Bull vs. Heifers	−0.0212	0.19	0.98	0.67, 1.42	0.91
Primi vs. Multi	−0.0927	0.20	0.91	0.62, 1.35	0.64

TSP – total serum protein, SEM – standard error of the mean, OR – odds ratio (an OR > 1 indicates increased odds of the outcome in the first group listed in the comparison, whereas an OR < 1 indicates decreased odds); [1] bull or heifer calf born from a primi- (Primi) or multiparous (Multi) cow; [2] treatment with antibiotic, anti-inflammatory drug or both