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Preweaning calf transportation practices in the United States: A cross-sectional survey of dairies, haulers, and calf raisers

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ABSTRACT

Transportation is a significant stressor for cattle, but research is lacking regarding preweaning dairy calf transport practices in the United States. Improving our understanding of calf transportation practices can inform management practices that minimize welfare challenges of transport. The objectives of this study were to (1) describe current industry practices regarding transportation of preweaning dairy and beef-on-dairy crossbred calves, (2) determine differences in pre-transport management on dairies between replacement heifers, beef-on-dairy crossbreds, and dairy bull calves, and (3) identify outreach and research needs to address calf welfare concerns related to transportation. Dairy producers, calf raisers, or other individuals receiving transported calves, and haulers were recruited through digital advertisement, email, and extension agents to complete an online survey in 2023. Survey topics for dairy producers included pre-transport practices (e.g., colostrum management, health evaluations, marketing), and topics for operations that received transported calves included calf condition at arrival, preweaning disease incidence, and preconditioning requirements. Haulers were asked questions related to their route demographics (e.g., travel distance, number of stops, destination). Wilcoxon signed rank, Kruskal–Wallis, or McNemar tests were conducted to determine differences in calf management practices; the predictor of interest was calf class (replacement heifer, beef-on-dairy, dairy bull), and outcomes of interest included age at transport, colostrum timing and quantity, feeding and preconditioning practices before transport, calf health characteristics pre- and post-transport, and transport distance and duration. A total of 123 responses were accepted for analysis (n = 69 dairy producers; 29 operations that received transported calves; 25 haulers). Replacement heifers were transported at older ages, compared with beef-on-dairy calves, but no difference in age was found between replacement heifers and bulls or beef-on-dairy and bulls. More dairy operations reported vaccinating replacement heifers versus nonreplacement calves. Operations that received transported calves reported considerable variability in preweaning morbidity and mortality rates. Stakeholder groups also highlighted the need for best practice recommendations related to transport and increased communication and collaboration between dairies and calf raisers. Although this study was limited by a small sample size, our findings provide a deeper understanding of transport practices in the United States, which can be used to inform research and outreach efforts to promote the health and welfare of dairy calves and support the longevity of the dairy industry.
Key words: calf health, fitness for transport, neonate

INTRODUCTION

Optimizing early life management is essential for the long-term health, productivity, and welfare of dairy calves. Transportation is a necessary component of the United States supply production chain and has been recognized as a significant challenge for young calves early in life (Alley et al., 2021; Creutzinger et al., 2021; Roadknight et al., 2021; Cramer et al., 2024b). During transportation, calves can experience several compounding stressors, such as food and water deprivation, commingling, improper handling, and extreme weather conditions, which are especially challenging for calves due to their underdeveloped immune systems and limited stress response (Trunkfield and Broom, 1990; Pardon et al., 2015; Hulbert and Moisá, 2016). In the United States, transporting young calves from dairy farms soon after birth is common practice, with an estimated 6 million calves sold and transported annually (Edwards-Callaway et al., 2019; Bolton and von Keyserlingk, 2021; USDA, 2022, 2024; Cramer et al., 2024a). Although broad, categorical challenges relative to transporting young calves have been well-documented,

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there is limited information on specific transport practices used in the United States (Creutzinger et al., 2021). This knowledge gap thwarts efforts to evaluate and mitigate the potentially deleterious impacts of transport on calf health, welfare, and performance, highlighting the need for detailed data to help guide improvements in current practices and calf-level outcomes.

Researchers have found that management practices sometimes differ between replacement and nonreplacement calves, particularly with regard to male calves and colostrum management (Shivley et al., 2019; Creutzinger et al., 2021; Cramer et al., 2024b). Male dairy calves have traditionally been considered to hold low market value, which may influence suboptimal standards of care compared with replacement heifers after birth (Cave et al., 2005; Creutzinger et al., 2021). In addition, the increased use of beef semen on dairy operations has also led to a rise in the number of nonreplacement beef-on-dairy calves sold and transported in early life (McCabe et al., 2022; Creutzinger et al., 2022; Felix et al., 2023). As the nonreplacement calf sector continues to expand in the United States, it is necessary to understand their unique management and marketing challenges to ensure good health, welfare, and performance.

Ensuring health and welfare as calves transition into a calf-raising facility requires a multifaceted approach across the supply chain, which begins at the dairy farm with optimal pre-transport management, continues through marketing and transportation, and concludes at the calves' destination with high-quality care on arrival. Achieving this requires a comprehensive understanding of each stakeholder's role in the calf supply chain to guide improvements effectively. Therefore, the objectives of this study were to (1) describe current industry practices regarding the transportation of preweaning dairy and beef-on-dairy calves, (2) determine differences in pre-transport management on dairies between replacement heifer, beef-on-dairy, and dairy bull calves, and (3) identify outreach and research needs to address calf welfare concerns related to transportation.

MATERIALS AND METHODS

This study was reported using guidance from the STROBE-Vet Statement (O'Connor et al., 2016). This research was approved through the Colorado State University (**CSU**) Institutional Review Board (#4250) before project initiation.

Participant Population and Recruitment

A cross-sectional survey intended for individuals involved in making decisions about transporting and receiving preweaning dairy or beef-on-dairy calves within the United States was conducted from 2023 to 2024. Specifically, participants eligible for participation in this study included producers, owners, operators, managers, employees, or veterinarians of dairy operations, calf ranches, heifer-raising facilities, auctions, and veal operations, as well as haulers responsible for transporting calves. Participant recruitment began in March 2023 and ended in January 2024. In-person recruitment began at the Dairy Calf and Heifer Association (**DCHA**) conference hosted in Prior Lake, Minnesota, in March 2023. Participants were also recruited via email, newsletters, and websites hosted by industry and extension groups, such as DCHA (https://calfandheifer.org/), Progressive Dairy (https://www.agproud.com/topics/99-progressive-dairy), Hoard's Dairyman Magazine (https://hoards.com/), and University of Wisconsin–Madison Extension (https://extension.wisc.edu/). Respondents were offered a $15 gift card for their participation. Those who completed the survey and chose to receive a gift card were directed to a separate link to provide their email address to maintain anonymity and confidentiality.

Survey Format and Content

The self-administered survey was developed by a research team with expertise in animal welfare, calf health and management, veterinary medicine, statistics, and survey development and analysis. The survey was entered into online survey software (Qualtrics XM Platform, Qualtrics International Inc., Seattle, WA) to facilitate distribution. Before distribution, survey questions were reviewed by the research team, practicing veterinarians, and industry professionals who work closely with dairies or calf ranches to ensure clarity and validity. The survey was piloted by 3 graduate students from the CSU Department of Animal Sciences to ensure usability and function (i.e., branching, clarity, flow). The survey used a branching method, which directed respondents to one of 4 complementary surveys based on their role in the calf supply chain. All surveys incorporated skip logic whereby certain questions were omitted based on participants' responses. Respondents were required to select one role that best described their operation: (1) dairy operations that sell or contract out calf raising for preweaning calves, (2) dairy operations that transport and raise preweaning calves at another location they owned, (3) operations that receive preweaning calves after transport (e.g., auctions, livestock markets, calf ranches, and so on), and (4) haulers responsible for transporting preweaning calves. Respondents working on dairies that sold or contracted rearing for preweaning calves received a survey with 28 to 69 questions focused on pre-transport practices, including age at transport, colostrum management, health evaluations, and preconditioning, a term used to define management practices designed to

prepare an animal for the next phase of production (Hilton, 2015). Respondents working on dairies that transported and raised preweaning calves at a different location they owned received a survey with 32 to 78 questions, which included the same pre-transport topics listed above, as well as additional questions about the calves' condition upon arrival at their destination. Respondents who worked on operations that received preweaning calves completed a survey with 27 to 30 questions focusing on calf condition upon arrival, the source of the calves, and preconditioning requirements. Haulers who transported preweaning calves received a survey containing 16 to 18 questions about transport practices, including travel distance and duration, the number of stops per trip, and the calves' source and destination. All respondents across all roles (i.e., dairies, calf raisers, and haulers) received questions about training and respondent demographics, as well as challenges and opportunities relating to calf transportation. Question types included multiple-choice, select-all-that-apply, Likert scale, and free response. The survey was designed to take between 15 and 20 min, with exact times varying based on participants' responses. Respondents could stop the survey at any time, in accordance with IRB protocol. The only required questions were to confirm consent and that respondents were ≥18 yr; thus, it is possible for questions to have varying denominators. All questionnaires are available in the supplemental material (see Notes).

Bot Protection and Detection

Security measures were implemented in the survey using Qualtrics security settings to prevent fraudulent responses from online channels. This included Google's Completely Automated Public Turing Test to tell Computers and Humans Apart (**reCAPTCHA**) V3, which evaluates criteria such as typing speed and IP address activity (Google Developers, 2020; Qualtrics XM Platform, Qualtrics International Inc., Seattle, WA; Griffin et al., 2022). Additionally, bot detection, which is a Qualtrics survey field that indicates a reCAPTCHA score that relates to the probability that the respondent is a bot, and password protection were applied to further secure the survey (Griffin et al., 2022). However, similar to previous reports, sophisticated bots may still be able to bypass these security measures (Teitcher et al., 2015; Godinho et al., 2020; Griffin et al., 2022). The initial data collection was compromised on May 1, 2023. A surge of survey responses in a 24-h time frame alerted the research team to a survey breach. The research team was able to confirm fraudulent responses by analyzing the email addresses provided by respondents, as described in previous literature (Teitcher et al., 2015; Storozuk et al., 2020; Griffin et al., 2022). After initial bot detection, the survey was closed temporarily on May 2, 2023. In the second wave of data collection, the recruitment strategy was modified to have multiple unique survey links (the questions remained the same) to be shared through specific distribution channels so that any additional data breaches could be traced back to the distribution channel source and addressed without compromising other channels. This allowed the research team to detect additional bot responses from an individual survey link on October 19, 2023.

Data Processing and Statistical Analysis

The research team used a 2-part data cleaning protocol modified from previous literature (Teitcher et al., 2015; Storozuk et al., 2020; Griffin et al., 2022). The first stage of the data cleaning protocol was performed in Qualtrics utilizing the filter feature (Qualtrics XM Platform, Qualtrics International Inc., Seattle, WA). The filter feature was used to remove responses that (1) did not complete at least 70% of the survey (Griffin et al., 2022) and (2) responses with a reCAPTCHA score less than 0.5, as suggested by Google's developer guide (Google Developers, 2020, Mountain View, CA; Qualtrics XM Platform, Qualtrics International Inc., Seattle, WA). After filtering was completed in Qualtrics, cleaned data were exported into Microsoft Excel (Microsoft Corporation, Redmond, WA). Data were then filtered to identify and remove all survey responses recorded between May 1 and 2 and October 19, 2022, due to bot compromise. Respondents that indicated their operation was located outside of the United States in the demographics question were also removed. Finally, the remaining responses were checked for conflicting data as described in Griffin et al. (2022). These included inconsistencies in demographic and population responses (e.g., respondents who reported transporting over 1,000 preweaning calves from their dairy in the last year and also reported having 80–200 head of lactating cows).

For statistical analyses, categories with fewer than 5 responses were combined with the closest similar category. Age categories "4-7 d," "7-14 d," and "≥14 d but before weaning" were merged into a single category "≥4 d." Total colostrum categories "1.9 L" and "2.8 L" were merged into a single category "<3.8 L." Finally, timing of colostrum categories "3-4 h" and " >4 h" were merged into "≥3 h." Questions related to colostrum quality were removed from statistical analysis due to categories having fewer than 5 responses and being unable to combine categories. Written responses in the "Other" category were categorized, if applicable. For example, "physical markings on calves" was categorized into "paint or chalk marks" responses for colostrum verification. Additionally, the response "calves are transported 4 h after the 3rd bottle" was categorized as "No" for the question regarding whether calves have access to a milk feeding within 2

Table 1. Number and percentage (n, %) of dairy operations that sent calves to each destination, by calf class

Item	Replacement heifer (n = 40)	Beef-on-dairy (n = 58)	Dairy bull (n = 56)
Another owned facility	1, 3	1, 2	1, 2
Auction or livestock market	4, 10	19, 33	23, 40
Calf dealer or jockey	1, 3	14, 24	16, 28
Calf ranch or heifer raiser	31, 78	19, 33	11, 19
Direct to slaughter	0	0	2, 4
Veal	0	2, 3	0
Other	3, 8	2, 3	3, 5
Did not answer	0	1, 2	1, 2

Table 2. Number and percentage (n, %) of all dairy operations that reported transporting the majority of calves (>50%) in each age category in 2022, by calf class

Age	Replacement heifer (n = 40)	Beef-on-dairy (n = 57)	Dairy bull (n = 56)
<24 h	9, 22.5	11, 19.3	11, 19.6
1 d	4, 10	9, 15.8	8, 14.3
2 d	7, 17.5	10, 17.5	9, 16.1
3 d	5, 12.5	10, 17.5	8, 14.3
≥4–7 d[1]	10, 25	15, 26.3	18, 32.1
7–14 d[1]	2, 5	1, 1.75	1, 1.8
≥14 d, but before weaning[1]	3, 7.5	1, 1.75	1, 1.8

[1]The categories "4-7 d," "7-14 d," and "≥14 d but before weaning" were combined into ≥4 d for analysis.

h before transport. Written responses that were vague or could not be recategorized (e.g., "depends," "not sure," "feed 3 times a day") were excluded from the analysis for that variable. Missing responses were excluded for each question, resulting in different sample sizes. Statistical analysis was performed using R Software (v4.4.0, R Core Team, 2021, https://www.r-project.org/), and summary statistics were calculated for all variables.

The sample size was based on the availability of respondents, and no formal sample size calculation was completed, given the paucity of existing calf transportation data in the United States. For objective 1, descriptive summaries of current industry practices regarding the transportation of preweaning dairy and beef-on-dairy crossbred calves were reported for each calf class using frequency tables. Responses were compared within a sector (i.e., responses for dairy operations were compared with other dairy operations).

For objective 2, statistical analyses using paired data were conducted to determine differences in management practices on the dairy farm before transport. The predictor of interest was calf class (categorical; replacement heifer, beef-on-dairy, dairy bull). Statistical analysis was performed for each outcome variable of interest using either Wilcoxon signed rank, Kruskal–Wallis, or McNemar tests. For each analysis between the predictor (calf class) and the outcome of interest, 3 pairwise tests were performed between the 3 calf classes. The first test compared replacement heifers with beef-on-dairy, the second compared replacement heifers with dairy bull calves, and the third compared beef-on-dairy with dairy bull calves. Wilcoxon signed rank tests were performed for the outcome variables age at transport (categorical; <24 h, 1 d, 2 d, 3 d, ≥4 d) and timing after birth to first colostrum feeding (categorical; <1 h, 1–2 h, ≥3 h) to compare differences in practice between the predictor variable (calf class). A Holm-Bonferroni correction was applied to account for multiple comparisons. Kruskal–Wallis tests were performed for the outcome variables median distance (continuous), median duration (continuous), and motivation to improve colostrum management (continuous) with Holm-Bonferroni correction to compare differences in practice between the predictor variable (calf class). Finally, McNemar tests were performed for the outcome variables total colostrum quantity (categorical; <3.8 L, ≥3.8 L), milk feeding before transport (categorical; yes, no), and access to water immediately before transport (categorical; yes, no) following the same procedure used for the previous 2 tests. Significance was defined as $P \leq 0.05$. Wilcoxon signed rank, Kruskal–Wallis, and McNemar tests were used to analyze paired data, so only dairy operations with multiple comparisons (i.e., transported more than one calf class type) and that responded for a given set of questions (e.g., age at transport, timing of colostrum, average distance, average duration, colostrum quantity, milk feeding before transport, access to water before transport, fitness for transport, and preconditioning practices) were included for analysis.

For objective 3, frequency tables were used to summarize outreach and research needs related to calf transport welfare, highlighting common challenges across industry sectors.

RESULTS

A total of 936 participants responded to the survey, and 781 responses were removed due to completion rates <70% (n = 316), reCAPTCHA scores <0.5 (n = 278), bot suspicion (n = 289), and bot detection (n = 239); these categories were not mutually exclusive. One hundred and 23 responses were included in the final analysis. Due to the nature of the survey distribution through various media sites, the exact survey response rate is unknown.

Demographics for All Respondents Across All Operation Types

Approximately half (52.8%, 65/123) of respondents identified as male, were between the ages of 30 and 39 (24.4%, 30/123) or 40 and 49 (25.1%, 31/123), and were

Table 3. Pairwise comparisons[1] of calf age at transport on dairy operations (n, %) that reported transporting both replacement heifer and beef-on-dairy calves, replacement heifer and dairy bull calves, or beef-on-dairy and dairy bull calves in 2022

	Comparison 1,[2] n = 36 $P = 0.03$, V = 76		Comparison 2,[3] n = 31 $P = 0.2$, V = 56.5		Comparison 3,[4] n = 48 $P = 0.6$, V = 14	
Age	Replacement heifer	Beef-on-dairy	Replacement heifer	Dairy bull	Beef-on-dairy	Dairy bull
<24 h	9, 25	11, 30.6	8, 25.8	10, 32.3	9, 18.8	10, 20.8
1 d	4, 11.1	6, 16.7	4, 12.9	6, 19.4	8, 16.7	7, 14.6
2 d	6, 16.7	6, 16.7	6, 19.4	4, 12.9	8, 16.7	6, 12.5
3 d	5, 13.9	7, 19.4	4, 12.9	4, 12.9	8, 16.7	8, 16.7
≥4 d[5]	12, 33.3	6, 16.7	9, 29	7, 22.6	15, 31.3	17, 35.4

[1]A Wilcoxon signed rank test was performed between each calf class. V is the test statistic.

[2]Only dairy operations (n = 36) that transported both replacement heifers and beef-on-dairy calves in 2022 were included in this pairwise analysis.

[3]Only dairy operations (n = 31) that transported both replacement heifer and dairy bull calves in 2022 were included in this pairwise analysis.

[4]Only dairy operations (n = 49) that transported both beef-on-dairy and dairy bull calves in 2022 were included in this pairwise analysis. One operation did not respond for beef-on-dairy or dairy bull calves; therefore, this operation was excluded from analysis.

[5]Combined categories "4-7 d," "7-14 d," and "≥14 d but before weaning."

owners (48.0%, 47/98) or managers (35.7%, 35/98) of their operation.

Dairy Operations

A total of 69 respondents indicated they worked on dairy operations. Of these, 33 reported either contracting their calf raising at another location or selling some or all of their preweaning calves (i.e., calves were transported to a facility they did not own), and 36 reported transporting and raising preweaning calves at another location they owned; these results are combined and presented in this section for dairy operations, unless otherwise noted. Of the 69 total dairy operations, 40 transported preweaning replacement heifers, 58 transported beef-on-dairy crossbred calves, and 57 transported dairy bull calves (n = 57; categories are not mutually exclusive). Thirty-six operations transported both replacement heifers and beef-on-dairy calves, 31 operations transported both replacement heifers and dairy bull calves, and 49 operations transported both beef-on-dairy and dairy bull calves. Respondents indicated a total of 284,597 replacement heifers, 263,104 beef-on-dairy crossbred calves, and 33,146 dairy bull calves were transported before weaning over the previous year. Respondents from dairy operations were located in the Midwest (64%, 37/58), West (19%, 11/58), Northeast (10%, 6/58), Southeast (3%, 2/58), and Southwest (3%, 2/58).

Destination, Distance, and Duration of Transport

Operations most frequently shipped replacement heifers to a calf ranch or heifer-raising facility (78%, 31/40; Table 1). Equal numbers of operations sent beef-on-dairy calves to an auction or livestock market (33%, 19/58) or calf ranch (33%, 19/58; Table 1). Operations most frequently shipped dairy bull calves to an auction or livestock market (40%, 23/57; Table 1).

Producers were asked to report the average distance and duration traveled for the majority of calves that left their operation. The median transport distance was 81 km (first quartile: 24 km, third quartile: 724 km), 64 km (first quartile: 24 km, third quartile: 113 km), and 48 km (first quartile: 24 km, third quartile: 72 km) for replacement heifers, beef-on-dairy, and dairy bull calves, respectively. There was no difference in distance traveled between calf classes (all $P \geq 0.4$). Additionally, there was no difference in the duration of travel between calf classes, whereby median travel duration was 1.3 h (first quartile: 0.9, third quartile: 8.5), 1.0 h (first quartile: 0.5, third quartile: 2.0), and 1.0 h (first quartile: 0.5, third quartile: 1.0) for replacement heifers, beef-on-dairy, and dairy bull calves, respectively (all $P > 0.7$).

Age at Transport

The age at transport reported for the majority of calves on an operation by calf class is described in Table 2. Supplemental Table S1 (see Notes) describes age at transport, by calf class and region. Age at transport was different between replacement heifers and beef-on-dairy, with replacement heifers transported at older ages ($P = 0.03$; Table 3). There was no difference in age at transport between replacement heifers and bull calves ($P = 0.2$) or beef-on-dairy and bull calves ($P = 0.6$; Table 3).

Table 4. Timing of the first colostrum feeding in 2022 for the majority of calves (>50%) before transport reported by all dairy operations (n, %), by calf class

Time after birth	Replacement heifer (n = 40)	Beef-on-dairy (n = 58)	Dairy bull (n = 56)
<1 h	18, 45	20, 34.5	24, 42.9
1 to 2 h	17, 42.5	27, 46.6	19, 33.9
≥3 h	5, 12.5	11, 19.0	13, 23.2

Table 5. Number and percentage (n, %) of all dairy operations that included each practice in their preconditioning program for calves before transport in 2022, by calf class

Practice	Replacement heifer (n = 38)	Beef-on-dairy (n = 55)	Dairy bull (n = 54)
Antibiotics	8, 21.1	5, 9.1	6, 11.1
Electrolytes	11, 28.9	33, 60.0	12, 22.2
Navel antiseptic	33, 86.8	50, 90.9	48, 88.9
Supplements	10, 26.3	14, 25.5	15, 27.8
NSAID[1]	5, 13.2	4, 7.3	4, 7.4
Vaccines	23, 60.5	19, 34.5	13, 24.1
Nothing	3, 7.9	7, 12.7	6, 11.1

[1]Nonsteroidal anti-inflammatory drugs.

Colostrum Management and Milk Feeding Practices

All but one dairy operation reported feeding colostrum to all calves regardless of class, with the exception being one operation that provided colostrum to replacement heifers and beef-on-dairy calves but not to bull calves. Overall, similar practices in total colostrum quantity were reported across calf classes, with 77.5% (31/40), 75.9% (44/58), and 76.8% (43/56) of operations providing ≥3.8 L of colostrum to replacement heifers, beef-on-dairy, and dairy bull calves, respectively (all $P = 1.0$). Timing after birth to the first colostrum feeding by calf class was similar between all calf classes ($P > 0.1$; Table 4). Supplemental Table S2 (see Notes) describes timing of the first colostrum feeding, by calf class and region. Operations provided colostrum with a Brix reading ≥22 (IgG >50 g/L) to replacement heifers (39.1%, 27/40), beef-on-dairy (51.7%, 30/58), and dairy bull calves (45.5%, 25/56). Over half of the operations used paper records to verify colostrum administration for replacement heifers (59.0%, 23/39), beef-on-dairy (56.9%, 33/58), and dairy bull calves (53.6%, 30/56).

Respondents were asked what factors would influence their decision to improve colostrum practices for each calf class. Approximately half of respondents reported they had an excellent colostrum management program in place for replacement heifers (52.5%, 21/40), beef-on-dairy (51.7%, 30/58), and dairy bull calves (46.4%, 26/56). Respondents reported that improvements to calf health would help influence their decision to improve colostrum practices for replacement heifers (65.0%, 26/40), beef-on-dairy (53.4%, 31/58), and dairy bull calves (50.0%, 28/56). Additionally, employee training would influence operations' decision to improve colostrum practices for replacement heifers (30.0%, 12/40), beef-on-dairy (32.8%, 19/58), and dairy bull calves (26.8%, 15/56).

There was no difference in the percentage of operations that reported providing milk within 2 h before transport for replacement heifer (66.7%, 24/36), beef-on-dairy (69.8%, 37/53), or dairy bull calves (76.9%, 40/52; all $P = 1.0$). There was no difference in the percentage of operations that reported providing access to water immediately before transport for replacement heifers (50.0%, 19/38), beef-on-dairy (45.6%, 26/57), or dairy bull calves (52.7%, 29/55; all $P \geq 0.2$).

Preconditioning and Fitness for Transport

Preconditioning practices reported by all operations for the majority of calves on their operations, by calf class, are outlined in Table 5. Operations reported a significant difference in vaccination administration between replacement heifer and beef-on-dairy calves ($P < 0.05$), as well as between replacement heifer and dairy bull calves ($P < 0.05$; Table 6). There was no difference in any preconditioning practices reported by operations for beef-on-dairy and dairy bull calves ($P > 0.05$; Table 6). Supplemental Table S3 (see Notes) describes preconditioning practices by calf class and region. Respondents were asked whether their operation would be willing to implement additional preconditioning practices to their current management protocol; the majority of operations indicated "yes" or "maybe" for replacement heifers (81.6%, 31/38), beef-on-dairy (89.4%, 50/56), and dairy bull calves (89.1%, 49/55). When asked if they "conducted a formal health evaluation prior to transport," most operations reported doing so for replacement heifers (66.7%, 26/39), beef-on-dairy (70.2%, 40/57), and dairy bull calves (68.5%, 37/54). Fitness for transport criteria across all calf classes is reported in Table 7. There were no differences in fitness for transport criteria reported between replacement heifer and beef-on-dairy, replacement heifers and dairy bull, and beef-on-dairy and dairy bull calf classes (all $P \geq 0.02$; Table 8). Supplemental Table S4 (see Notes) describes fitness for transport criteria by calf class and region.

Training

The majority (93.3%, 56/60) of dairy operations provided some form of training to employees who handle calves before transport. Colostrum feeding (96.4%, 53/55), colostrum management (80.0%, 44/55), calf han-

Table 6. Pairwise comparisons[1] of preconditioning practices for calves before transport on dairy operations (n, %) that reported transporting both replacement heifer and beef-on-dairy calves, replacement heifer and dairy bull calves, or beef-on-dairy and dairy bull calves in 2022

	Comparison 1,[2] n = 33		Comparison 2,[3] n = 29		Comparison 3,[4] n = 46	
Practice	Replacement heifer	Beef-on-dairy	Replacement heifer	Dairy bull	Beef-on-dairy	Dairy bull
Antibiotics	7, 21.2	5, 15.2	7, 24.1	4, 13.8	4, 8.7	5, 10.9
Electrolytes	10, 30.3	8, 24.2	8, 27.6	8, 27.6	10, 21.7	11, 23.9
Navel antiseptic	32, 97	30, 90.9	27, 93.1	25, 86.2	42, 91.3	42, 91.3
Supplements	9, 27.3	5, 15.2	8, 27.6	6, 20.7	12, 26.1	13, 28.3
NSAID[5]	5, 15.2	3, 9.1	5, 17.2	3, 10.3	4, 8.7	4, 8.7
Vaccines	21, 63.6[a]	13, 39.4[b]	16, 55.2[a]	7, 24.1[b]	16, 34.8	13, 28.3
Nothing	3, 9.1	7, 21.2	1, 3.4	4, 13.8	5, 10.9	3, 6.5

[a,b]Superscripts within a row indicate significant differences in practices between calf classes ($P \leq 0.05$).

[1]A McNemar test was performed between each calf class for each practice.

[2]Only dairy operations (n = 36) that transported both replacement heifers and beef-on-dairy calves in 2022 were included in this pairwise analysis. Three operations did not provide a response for either replacement heifer or beef-on-dairy calves; therefore, these operations were excluded from analysis.

[3]Only dairy operations (n = 31) that transported both replacement heifer and dairy bull calves in 2022 were included in this pairwise analysis. Two operations did not provide responses for either replacement heifer or dairy bull calves; therefore, these operations were excluded from analysis.

[4]Only dairy operations (n = 49) that transported both beef-on-dairy and dairy bull calves in 2022 were included in this pairwise analysis. Three operations did not provide a response for either replacement heifer or beef-on-dairy calves; therefore, these operations were excluded from analysis.

[5]Nonsteroidal anti-inflammatory drugs.

dling (89.1%, 49/55), and newborn care (87.3%, 48/55) were the most frequently reported topics discussed in training programs across operations. Training was most often provided to employees through managers (92.7%, 51/55) or another employee (50.9%, 28/55). Operations also used instructional videos (40.0%, 22/55), training through their herd veterinarian (38.2%, 28/55), and the National Dairy Farmers Assuring Responsible Management Program (27.3%, 15/55).

Challenges and Resources

Dairy operations were asked to identify their 3 primary challenges regarding calf transportation from a list of 14 predefined options. The most frequently reported challenges identified by operations were economic, including labor costs and availability (33.3%, 19/57) and the low price of calves (29.8%, 17/57). Additionally, issues related to resources for calf care were highlighted, such as space availability in case of delayed calf pickup (28.1%, 16/57) and the lack of resources to house calves before transport (24.0%, 8/57). Transportation logistics, such as duration of travel and availability of haulers, were also common challenges (21.1%, 12/57). Only 3.5% (2/57) of respondents indicated that finding buyers for calves was a challenge. The resources identified by operations as most helpful in addressing these challenges included best practice recommendations (35.7%, 20/56), more options and markets for selling calves (32.1%, 18/56), and training programs for employees (37.5%, 21/56). The most common resource identified by half of operations was an increased premium or sale price for calves (50%, 28/56).

Post-Transport Practices for Dairies That Transported and Raised Their Own Calves at Another Location

Respondents (n = 36) who transported and raised their own calves at another location were asked about calf husbandry practices immediately after transport; 19 of these respondents opted to answer the questions related to post-transport practices. Seventy-nine percent (15/19) of operations conducted a formal health assessment, and 57.9% (11/19) collected blood samples to determine transfer of passive immunity for calves upon arrival to their facility. The condition of preweaning calves upon arrival is outlined in Table 9. Supplemental Table S5 (see Notes) describes the condition of calves upon arrival, by calf class and region. The median percentage of preweaning calves that arrived at operations with gastrointestinal issues (e.g., diarrhea) was 16.0% (first quartile: 7.0%, third quartile: 20.0%). The median percentage of preweaning calves experiencing respiratory problems (e.g., pneumonia) was 10.0% (first quartile: 6.25%, third quartile: 26.5%), and 3.0% (first quartile: 2.0%, third quartile: 6.5%) were affected by navel infections or inflammation. Additionally, respondents reported that ~5.0% (first quartile: 3.0%, third quartile: 13.8%) of preweaning calves died before weaning. The majority of respondents (94.4%, 17/18) provided training to

Table 7. Number and percentage (n, %) of all dairy operations that indicated they would deem a calf unfit for transport with each condition in 2022, by calf class

Condition	Replacement heifer (n = 40)	Beef-on-dairy (n = 56)	Dairy bull (n = 55)
Bone fractures	36, 90.0	53, 94.6	51, 92.7
Coat is still wet	34, 85.0	46, 82.1	47, 85.5
Dehydration	29, 72.5	43, 76.8	37, 67.3
Diarrhea/scours	28, 70.0	45, 80.4	44, 80.0
Difficulty breathing	32, 80.0	46, 82.1	45, 81.8
Extremely thin	23, 57.5	35, 62.5	33, 60.0
Has not received minimum feedings	27, 67.5	39, 69.6	35, 63.6
Navel inflammation	18, 45.0	35, 62.5	37, 67.3
No ID	30, 75.0	24, 42.9	22, 40.0
Premature	18, 45.0	36, 64.3	33, 60.0
Respiratory disease	30, 75.0	44, 78.6	42, 76.4
Severe lameness	32, 80.0	49, 87.5	47, 85.5
Unable to stand unassisted	31, 77.5	48, 85.7	46, 83.6
Unable to walk unassisted	27, 67.5	47, 83.9	44, 80.0

employees responsible for handling calves immediately after transport. The most prevalent training topics were calf handling (100%, 16/16) and disease identification (100%, 16/16). Additionally, operations identified newborn care (81.3%, 13/16), record keeping (68.8%, 11/16), and sanitation (81.3%, 13/16) as topics discussed in employee training. All operations (100%, 16/16) provided training to their employees through the manager, and over half (62.5%, 10/16) provided training through another employee. Over half (56.3%, 9/16) of operations used their herd veterinarian to provide training, and half (50.0%, 8/16) of operations used instructional videos.

Calf Raisers

Operation Characteristics. Twenty-nine respondents indicated they received transported calves. Most respondents indicated their operation type was calf raiser (83%, 24/29), followed by auction or livestock market (7%, 2/29), veal (3%, 1/29), and other (7%, 2/29). Most calf raisers were located in the Midwest (63%, 15/24), followed by the West (17%, 4/24), Northeast (8%, 2/24), Southwest (8%, 2/24), and Southeast (4%, 1/24). Of the 2 auction market respondents, 1 operation was located in the Midwest and 1 in the Northeast. The one veal facility was located in the Midwest. The 2 operations that reported "other" as their operation type were located in the Midwest. The majority (86.2%, 25/29) of calf-raising operations received preweaning calves directly from dairies, followed by auction or livestock markets (10.3%, 3/29) and veal operations (3.4%, 1/29). Respondents reported that their operations raised calves for beef production (33.3%, 8/24) or to serve as replacement heifers (25.0%, 6/24), with approximately half (41.7%, 10/24) of operations indicating they raised calves for both purposes. The number of calves on milk varied among operations, with 20.7% (6/29) with fewer than 80 head, 24.1% (7/29) with 80 to 200 head, 17.2% (5/29) with 200 to 500 head, and 31.0% (9/29) with over 1,000 head. Nearly all operations (92.9%, 26/28) received preweaning calves from multiple dairies. In the past year, the median proportion of calves purchased by the operation and later sold back to the dairy was 58.0% (first quartile: 35.0%, third quartile: 77.5%). Similarly, for calves purchased by the operation but not sold back to the dairy, the median proportion was 50.0% (first quartile: 24.0%, third quartile: 83.5%). The median proportion of calves that operations reported purchasing from auction markets or sale barns was 27.0% (first quartile: 10.5%, third quartile: 50.5%). Additionally, the median proportion of calves that all operations reported originating from another owned dairy was 25.0% (first quartile: 14.0%, third quartile: 50.0%).

The median percentage of preweaning calves that arrived at calf-raising operations in 2022 was 40.0% (first quartile: 20.0%, third quartile: 75.0%) Holstein heifers, 40.0% (first quartile: 19.0%, third quartile: 59.0%) beef-on-dairy crosses, and 25.0% (first quartile: 11.0%, third quartile: 60.0%) dairy bull calves. Among the operations that received preweaning calves, 39.3% (11/28) reported that the majority (>50%) were transported from dairies located less than 80 km from their operation. Additionally, one-quarter of operations reported that preweaning calves traveled distances of either 82 to 161 km (25.0%, 7/28) or 163 to 805 km (25.0%, 7/28), and 10.7% (3/28) reported receiving calves from dairies located 806 to 1,609 km away. The approximate age for the majority (>50%) of calves that arrived at operations within the last year varied between ≤24 h (17.9%, 5/28) and up to 7 to 14 d of age (3.6%, 1/28). Over half of operations reported the approximate age of calves at arrival to be 2 (32.1%, 9/28) or 3 d of age (21.6%, 6/28).

Health. Most calf-raising operations (93.1%, 27/29) conducted a formal assessment of calves upon arrival to their operation, but only half (55.2%, 16/29) collected blood

Table 8. Pairwise comparisons[1] of conditions that would deem a calf unfit for transport reported by dairy operations (n, %) that transported both replacement heifer and beef-on-dairy calves, replacement heifer and dairy bull calves, or beef-on-dairy and dairy bull calves in 2022

	Comparison 1,[2] n = 35		Comparison 2,[3] n = 30		Comparison 3,[4] n = 47	
Condition	Replacement heifer	Beef-on-dairy	Replacement heifer	Dairy bull	Beef-on-dairy	Dairy bull
Bone fractures	32, 91.4	33, 94.3	27, 90.0	28, 93.3	44, 93.6	44, 93.6
Coat is still wet	32, 91.4	28, 80.0	27, 90.0	25, 83.3	40, 85.1	41, 93.2
Dehydration	27, 77.1	25, 71.4	21, 70.0	17, 56.7	35, 74.5	32, 68.1
Diarrhea/scours	24, 68.6	25, 71.4	20, 66.7	20, 66.7	37, 78.7	37, 78.7
Difficulty breathing	27, 77.1	26, 74.3	22, 73.3	22, 73.3	38, 80.9	38, 80.9
Extremely thin	21, 60.0	20, 57.1	16, 53.3	16, 53.3	27, 57.4	28, 59.6
Has not received minimum feedings	25, 71.4	25, 71.4	21, 70.0	20, 66.7	33, 70.2	31, 66.0
Navel inflammation	15, 42.9	16, 45.7	14, 46.7	16, 53.3	29, 61.7	31, 66.0
No ID	27, 77.1[a]	18, 51.4[b]	22, 73.3	15, 50.0	20, 42.6	20, 42.6
Premature	18, 51.4	20, 57.1	13, 43.3	11, 36.7	28, 59.6	27, 57.4
Respiratory disease	26, 74.3	25, 71.4	21, 70.0	19, 63.3	36, 76.6	35, 74.5
Severe lameness	27, 77.1	29, 82.9	22, 73.3	23, 76.7	40, 85.1	39, 83.0
Unable to stand unassisted	26, 74.3	28, 80.0	21, 70.0	23, 76.7	39, 83.0	39, 83.0
Unable to walk unassisted	23, 65.7	27, 77.1	18, 60.0	21, 70.0	38, 80.9	37, 78.7

[a,b]Superscripts within a row indicate significant differences in practices between calf classes ($P \leq 0.05$).

[1]A McNemar test was performed between each calf class for each practice.

[2]Only dairy operations (n = 36) that transported both replacement heifers and beef-on-dairy calves in 2022 were included in this pairwise analysis. One operation did not provide a response for either replacement heifer or beef-on-dairy calves; therefore, these operations were excluded from analysis.

[3]Only dairy operations (n = 31) that transported both replacement heifer and dairy bull calves in 2022 were included in this pairwise analysis. One operation did not provide responses for either replacement heifer or dairy bull calves; therefore, this operation was excluded from analysis.

[4]Only dairy operations (n = 49) that transported both beef-on-dairy and dairy bull calves in 2022 were included in this pairwise analysis. Two operations did not provide a response for either beef-on-dairy or dairy bull calves; therefore, these operations were excluded from analysis.

samples to evaluate transfer of passive immunity. The proportion of calf-raising operations that reported suboptimal conditions in preweaning calves after transport is included in Table 9. Calf-raising operations were also asked about disease incidence during the preweaning period; the median incidence rate for gastrointestinal issues (i.e., diarrhea) was 22.0% (first quartile: 9.0%, third quartile: 50.25%). The median incidence rate for respiratory issues was 20.0% (first quartile: 11.0%, third quartile: 36.0%) and 7.0% (first quartile: 2.0%, third quartile: 10.0%) for navel infection or inflammation. The median preweaning mortality rate was 4.0% (first quartile: 2.0%, third quartile: 7.5%).

Practices Required from Source Dairies. The most frequently reported practice that calf raisers required from source dairies was colostrum (79.3%, 23/29). In contrast, fewer than one-quarter of operations required preconditioning practices for preweaning calves transported to their operation. Whereas only 24.1% of calf raisers required their source operation to provide milk before transport, over half (55.2%, 16/29) identified this as an important preconditioning aspect for calves on milk. Most calf raisers indicated a willingness to require source farms to implement additional preconditioning practices, with the majority responding "yes" or "maybe" (86.0%, 25/29).

Training. The majority (89.7%) of operations that received calves provided some form of training to employees who handle calves post-transport. Common topics included in employee training were calf handling (88.0%, 22/25), disease identification (80.0%, 20/25), newborn care (72.0%, 18/25), and sanitation (68.0%, 17/25). Managers were the primary source for providing training to employees (88.5%), with other employees (38.5%, 10/26) and the herd veterinarian (34.6%, 9/26) also used as training sources.

Challenges and Resources. The most common challenge identified on operations that receive calves was calf health or condition upon arrival (53.6%, 15/28). The distance of the calf-raising facility from the dairy operation (46.4%, 13/28) was the second most common challenge identified by operations, followed by calf health or condition during the milk-feeding phase (39.3%, 11/28). The top resource identified by operations that receive preweaning calves was increased preconditioning strategies (51.9%, 14/27). Additionally, best practice recommendations (48.1%, 13/27) and increased communication between the dairy and calf raiser by managers and leads (44.4%, 12/27) were common resources identified across operations.

Calf Haulers

Overview. This survey received responses from 25 haulers, representing ~66,200 total calves transported in 2022. Haulers were located in the West (32%, 8/25), Midwest (28%, 7/25), Northeast (30%, 5/25), Southwest

Table 9. Number and percentage (n, %) of dairy operations[1] and operations receiving calves that reported preweaning calves arrived at their facilities with the following conditions after transport in 2022

Condition	Dairy operations that transported and raised calves at another location (n = 13)	Operations receiving calves (n = 27)
Bone fractures	5, 38.5	8, 29.6
Dehydration	7, 53.8	16, 59.3
Diarrhea/scours	10, 76.9	20, 74.1
Difficulty breathing/labored breathing	9, 69.2	14, 51.9
Extremely thin (BCS <2)	0, 0	5, 18.5
Failed transfer of passive immunity	5, 38.5	13, 48.1
Navel inflammation/infection	6, 46.2	18, 66.7
Nonambulatory	5, 38.5	6, 22.2
Respiratory disease/pneumonia	4, 30.8	12, 44.4
Severe lameness/lame on one or more limbs	2, 15.4	8, 29.6

[1]Includes only dairy operations that transported and raised their own calves at another location.

(12%, 2/25), and Southeast (8%, 2/25); one hauler did not provide their region (4%, 1/25). The median number of calves <1 wk of age that haulers reported to have transported from dairies to calf-raising facilities in the last year was 1,200 calves (first quartile: 1,000, third quartile: 1,500). Haulers picked up calves from 2 (24.1%, 7/25), 3 (32.0%, 8/25), 4 (8.0%, 2/25), and more than 5 operations (28.0%, 7/25). They delivered calves to 2 (36.0%, 9/25), 3 (28.0%, 7/25), 4 (8.0%, 2/25), and more than 5 operations (20.0%, 5/25). When asked to identify the source of preweaning calves comprising the majority (>50%) of their pickups, 60% (15/25) of haulers indicated cow/calf ranches, 24% (6/25) indicated dairies, 8% (2/25) stated beef ranch, and 8% (2/25) reported other. They delivered the majority (>50%) of their calves on milk to a calf ranch (44.0%, 11/25), auction or livestock market (36.0%, 9/25), and veal operations (20%, 5/25).

Training. The majority (80.0%, 20/25) of haulers had more than 2 yr of experience in transporting calves on milk. Haulers who received training with specific information on transporting calves on milk (76.0%, 19/25) received training as often as monthly (47.4%, 9/25) or annually (47.4%, 9/25).

Challenges and Resources. The majority of haulers reported that calf health (60.0%, 15/25) and distance from the calf facility to the dairy (64.0%, 16/25) are challenges they face when transporting calves on milk. Resources that haulers most often identified as being most helpful to address these challenges were best practice recommendations (64.0%, 16/25) and increased communication between the dairy and calf ranch by managers and leads (68.0%, 17/25), followed by a better understanding of driver turnover or driver schedule (56.0%, 14/25), or both.

DISCUSSION

This study aimed to (1) describe current industry practices regarding the transportation of preweaning dairy and beef-on-dairy calves in the United States, (2) determine differences in pre-transport management between replacement heifer, beef-on-dairy, and dairy bull calves, and (3) identify outreach and research needs to address calf welfare concerns related to transportation.

Dairy Operations

Destination, Distance, and Duration of Transport. Most dairy operations that transported their replacement heifers reported transporting them directly to calf raisers. However, approximately one-quarter to one-third of operations transported beef-on-dairy and dairy bull calves to auctions, livestock markets, or another third-party facility (e.g., calf jockeys or dealers); these facilities serve as intermediaries in the calf marketing chain, purchasing and aggregating large calf cohorts for calf raisers. Maggard et al. (2024) also documented that approximately one-third of nonreplacement calves were sold more than once in Ohio. It is likely that geographic or farm size differences, or both, influence how calves are marketed in the United States, that is, small dairy operations may be less likely to have a relationship with a calf raiser and choose to sell their calves through an auction or livestock dealer. Indirect marketing via a third party can create further challenges for nonreplacement calves who have prolonged exposure to transport stressors such as commingling with unfamiliar animals, various handling techniques, and limited food and water access (Roadknight et al., 2021; Creutzinger et al., 2021; Cramer et al., 2024b). Therefore, when assessing a calf's fitness for transport, it is crucial to consider not only the initial journey but also the entire marketing process.

In this study, no differences were observed between calf classes in terms of the distance or duration of transport. The median distance and duration reported by dairy operations in our study were shorter in comparison to previous studies (Cave et al., 2005; Pempek et al., 2017;

Roadknight et al., 2021; Cramer et al., 2024a). Interestingly, the distance from the dairy to the calf-raising facility was a common challenge reported by both calf raisers and haulers in the present study, but few dairies reported this as a challenge. It is possible this was not reported as a challenge because dairy producers are not typically aware of their calves' destination, predominantly for male calves sold via third-party facility (Creutzinger et al., 2022). In contrast, haulers or calf raisers have a better understanding of calf movements along the production chain as well as the challenges calves may experience during and after transport. The disjointedness of the calf production chain presents a significant need and opportunity to assemble key groups (e.g., dairy producers, haulers, purchasers, raisers, veterinarians) involved in various aspects of calf rearing to facilitate knowledge sharing and the creation of responsible management recommendations for marketing and transport.

Colostrum Management and Milk Feeding Practices. All but one dairy operation reported feeding colostrum to all calves regardless of class, with the exception being an operation that provided colostrum to replacement heifer and beef-on-dairy calves but not bull calves. This finding adds to previous evidence that most operations provide colostrum to bull calves (Renaud et al., 2017; Shivley et al., 2019). However, a small percentage of producers still reported they do not provide colostrum to bull calves, highlighting a critical need for improvement in colostrum management on some farms to ensure that bull calves always receive colostrum (Renaud et al., 2017; Shivley et al., 2019). No difference in the timing of the first colostrum feeding after parturition was observed in our study. This contradicts previous studies documenting female replacement calves receive colostrum sooner than male calves (Shivley et al., 2019; Renaud et al., 2020; Cheng et al., 2024). This may reflect positive changes in the industry, limitations of self-reported survey data (discussed further in subsequent sections), or a combination thereof.

In our study, most operations provided ≥3.8 L of colostrum, with no differences observed between calf classes. Cheng et al. (2024) also reported the majority of dairy operations provided equal volumes of colostrum to bull and heifer calves. However, these findings contrast earlier studies that identified a trend in operations providing bull calves with a lower total volume of colostrum compared with heifer calves (Shivley et al., 2019; Renaud et al., 2020). Given the few differences in practice and the continued prevalence of failed transfer of passive immunity in both male and female calves, there remains a need for improved colostrum management across all calf classes, which should be addressed in future outreach and industry initiatives (Renaud et al., 2020; Wilson et al., 2023).

Whereas the present study found that most operations provided milk within 2 h of transport and half provided water immediately before transport, previous studies indicated that over half of nonreplacement dairy calves were dehydrated before transport and upon arrival at their destination (England et al., 2023; Cramer et al., 2024a; Maggard et al., 2024). Because milk and water provision during transport is uncommon due to logistical challenges, optimal nutrition at the dairy is essential to prepare calves for transport (Creutzinger et al., 2021; Cramer et al., 2024b). Data from calf raisers in this study suggest that current feeding practices are insufficient in preventing dehydration and hypoglycemia, highlighting the need to address nutrition at the dairy and throughout the marketing process (England et al., 2023; Maggard et al., 2024).

Preconditioning and Fitness for Transport. Although the majority of operations answered "yes" when asked if they conducted formal health evaluations before transporting calves, this may reflect a response bias. The definition of "formal health evaluation" was left up to interpretation by the respondent and therefore could include a variety of evaluation criteria. Furthermore, there was considerable variation in the criteria used to determine calves' fitness for transport across operations. Evaluating fitness for transport is critical to ensure that animals can withstand transportation without compromising their welfare (Edwards-Callaway et al., 2019). Most operations indicated that calves showing signs of dehydration, diarrhea, respiratory issues, or lameness would be deemed unfit for transport; however, up to 33%, 30%, 25%, and 20% of dairy operations in our study reported they would still transport calves with dehydration, diarrhea, respiratory issues, or lameness, respectively. Moreover, 5% to 55% of operations indicated they would still transport calves with any suspected illness or injury. Although these operations represented the minority in our study, the cumulative effect is significant, given that even a small proportion of operations allowing the transportation of unfit calves can translate to thousands of calves that are transported under poor health conditions every year.

Inconsistent criteria for assessing calf fitness can pose a significant risk to the health of all calves during transport because calves often commingle with animals from different operations, increasing their risk of pathogen exposure (Hulbert and Moisá, 2016). Transporting compromised calves from the dairy is likely one contributing factor to previous reports of calves arriving at their destination in suboptimal condition (Wilson et al., 2020b; Cramer et al., 2024a). Moreover, given that certain conditions such as dehydration, navel inflammation, and low BW have been linked to future calf morbidity and mortality (Winder et al., 2016; Renaud et al., 2018), it is essential to refrain from transporting these at-risk calves.

Notably, many calf raisers and dairy operations in the present study emphasized the need for clear recommendations on best practices regarding calf transport,

highlighting the industry's demand for structured guidance. Fitness for transport criteria for calves is critical to ensure that only healthy animals are transported. The Calf Care Quality Assurance (**CCQA**) Program outlines fitness for transport recommendations for young calves, developed by a diverse group of experts. These recommendations identify specific conditions that render calves unfit for transport, such as dehydration, poor body condition, lameness or nonambulatory, and active disease cases (CCQA, 2022). Considering the risks to welfare and public trust if young calves are transported in suboptimal condition (Cramer et al., 2024b), as well as producers' interest in best practice recommendations, promoting fitness for transport criteria should be a key focus for future outreach and industry initiatives.

Across all 3 calf classes, most operations transported calves at 3 d of age or younger, consistent with previous studies that reported calves were transported <7 d of age (Shivley et al., 2019; Wilson et al., 2020a; Creutzinger et al., 2022; Maggard et al., 2024). Given its influence on calf health and development, transport age has been identified as an important predictor for calf health outcomes following transport (Creutzinger et al., 2021). Recent studies by Marcato et al. (2020a,b) and Goetz et al. (2023a,b) found that calves transported at older ages had reduced incidences of diarrhea and respiratory disease, a more developed adaptive immune system, and improved growth.

Recognizing the challenges of transporting young calves, many countries have established regulations that focus on minimum age at transport requirements to help address these issues (Council of the European Union, 2004; Animal Health Australia, 2012; New Zealand Government, 2018). However, in the United States, there are no federal regulations regarding the minimum age for calf transport (United States Code, 1994). Our study identified space availability as a potential barrier to keeping calves at the source dairy for a longer period. Therefore, operational and logistical factors need to be considered when assessing the potential effects of delayed transport in the United States.

Most respondents from dairy operations expressed a willingness to adopt additional preconditioning practices. Whereas navel dipping was widely performed across all calf classes, fewer than half of the operations in our study reported implementing other preconditioning measures. These findings suggest that, although operations recognize the potential benefits of preconditioning, there are current barriers to its implementation. For example, dairy producers' lack of awareness regarding calf destination influences their ability to provide preconditioning measures, such as vaccination (Creutzinger et al., 2022). We also identified financial constraints, such as labor costs and low calf sales prices, as challenges for dairy operations, which may explain why preconditioning practices are currently limited. Creutzinger et al. (2022) reported that dairy producers were generally reluctant to dedicate valuable resources to calves when they received little compensation at the time of sale. Research has shown that a price premium for healthier, more vigorous calves would be a stronger motivator for dairy producers to improve male calf care (Wilson et al., 2023). Offering financial incentives, such as premiums per head, could encourage dairy operations to implement additional practices that can improve calf health and welfare (Creutzinger et al., 2022).

The majority of respondents in the present study identified as male, and the largest proportion were owners or managers of their operations. These findings align with demographic trends reported in recent surveys on male calf care practices by Wilson et al. (2023) and Creutzinger et al. (2022), which suggest that male producers are most often involved in calf transport decisions, and owners and managers are most often providing information on calf transport and management practices. Whereas owners and managers typically have authority over operational decisions and oversight of practices, they may be disconnected from the realities of daily tasks, such as marketing and transportation, which are often carried out by employees or staff members (Durst et al., 2018). As a result, their responses might not fully reflect the day-to-day implementation of guidelines, adherence to protocols, or the extent to which employees are aware of and meet operational expectations.

Calf Raisers Receiving Preweaning Calves. Calf raisers reported preweaning calves traveled varying distances from the source dairy to their operation, with more than one-third of operations reporting calves traveled 161 km or more. This is a significant contrast from previous literature related to off-site heifer rearing, where less than 6% of dairy operations reported transporting calves 161 km or more (USDA, 2016). Due to the absence of a standardized traceability system for young calves in the United States (Charlebois et al., 2014), comprehensive data on calf transport distance or duration are limited (Creutzinger et al., 2021). Our results suggest that calves, or certain calf classes, may travel greater distances than previously recorded to reach calf raisers. However, additional data on transport practices in the United States are needed to confirm this.

Very few calf raisers required source dairies to provide preconditioning practices before transport in our study. Most calf raisers described their operations as calf ranches, making the lack of preconditioning requirements interesting. Calf ranches invest significant time and resources into raising preweaning calves and may likely benefit from preconditioning practices to reduce morbidity, mortality, and production losses, such as co-

lostrum, vaccination, and so on. Similar to dairy operations, the majority of calf raisers indicated a willingness to require additional preconditioning practices for calves before transport. Whereas both sectors are willing to adopt these practices, a transaction is needed to facilitate implementation, likely in the form of an incentive. However, determining who should provide these incentives remains a significant challenge, and deciding who bears the responsibility and how to justify the associated costs requires further investigation. It may be beneficial to calf ranches to initially absorb higher costs for better calf care at the source dairy farm, as this could translate to improved calf health, reduced medical expenses, and enhanced productivity over time (Creutzinger et al., 2022). Further research is needed to explore effective ways to foster collaboration and establish clear exchanges between sectors to promote improved calf care practices.

Calf health was identified as a primary challenge for calf raisers and haulers in our survey, but not for dairy operations. This may be due to the limited calf-level feedback dairies receive after calves are sold from their operations. Previous survey data reported more than half of dairies received any type of feedback on their calves (Cheng et al., 2024), which suggests that the majority of producers have limited involvement with calves after they are sold, especially nonreplacement calves that most likely will not return to the dairy operation. This communication gap could be preventing dairy operations from fully considering or investing in, or both, the long-term outcomes of their management practices for this calf population. In support of this, Creutzinger et al. (2022) documented dairy producers sometimes perceive an absence of responsibility for future male calf health due to the disjointedness of the supply chain and limited access to information at the calf level after sale. Addressing this disconnect by fostering better communication and collaboration between these sectors is essential to improving calf health and enhancing the efficiency and sustainability of the production system.

Haulers Transporting Preweaning Calves. Haulers in our study most often received and delivered calves to multiple operations, including dairies, calf ranches, cow-calf ranches, veal facilities, sale yards, and auctions, highlighting the breadth and variability of calf movement across different sectors of the industry. Additionally, haulers reported transporting more than 1,000 calves less than 1 wk of age in 2022. At less than 1 wk of age, calves may undergo long transport distances and multiple transport events, with exposure to challenges such as commingling with unfamiliar animals and prolonged fasting (Creutzinger et al., 2021). These findings emphasize the complexity of calf transport, highlighting the need for management strategies to mitigate stress and health risks associated with transporting young calves.

Training for Employees or Haulers Responsible for Handling Preweaning Calves. When developed and delivered correctly, training has been shown to positively influence animal welfare and worker health and safety (Adams et al., 2016; Hagevoort and Román-Muñiz, 2019). Many haulers reported receiving training from quality assurance (**QA**) programs, such as Beef Quality Assurance Transportation (National Cattlemen's Beef Association, 2021) and CCQA. In contrast, dairy and calf-raising operations rarely reported utilizing these programs for employee training, instead relying on managers and other employees for employee training. This presents an opportunity to expand the use of QA programs to promote more uniform and calf-specific training across dairy and calf-raising operations. Continued outreach and promotion of these QA programs, both in person and online, are essential to ensure they reach their intended audience and drive greater adoption across the industry.

Some limitations should be considered when interpreting the results of the present study, such as a smaller sample size, bot compromise, and the potential for selection and response bias. First, although steps were taken to achieve a larger sample size, such as extending the recruitment deadline and recruiting through various outlets, the number of respondents relative to the target population remained low. The length of the survey, specifically for dairy and calf-raising operations, may have resulted in a response drop-off. Additionally, although farm lists for dairies are available for many states, to our knowledge, this does not exist yet for calf-raising facilities or haulers. The use of an online survey also likely limited participation from producers with restricted internet access, such as members of Amish communities. Using pairwise comparisons limited analysis to those operations that transported at least 2 calf classes; thus, it is possible that trends for calf practices were not noted if operations only transported one class of calves. Nonetheless, this is the first study to characterize calf transport practices in the United States, and valuable insights were obtained. Next, a significant influx of bot responses on 2 separate occasions resulted in the loss of all survey data collected on those dates, and we were unable to distinguish between genuine and bot submissions on these days. Thus, this may have led to a loss of potentially credible survey responses for those dates. Finally, we used organizations, such as DCHA, Progressive Dairy, and Hoards Dairyman, to distribute the survey, which may have led to possible selection bias. It is possible that more progressive producers would be members of these organizations and, therefore, may have more optimal management practices and also be more interested in participating in this research. Specifically, our recruitment through the University of Wisconsin-Madison Extension Office likely overrepresented individuals who are

already engaged with the university and, as a result, may be more receptive to improving practices. Furthermore, our results relied on self-reporting by those working on operations, and thus responses were susceptible to potential response bias. Survey respondents may have incorrectly recalled specific practices for different calf classes (recall bias), or they may have felt compelled by social pressures to report practices that align with positive public perceptions (social desirability bias; Althubaiti, 2016). As Creutzinger et al. (2022) suggests, producers with established, positive relationships with extension offices or veterinarians are often more progressive in their dairy management approaches. This may have skewed the sample toward individuals more receptive to improving practices, potentially limiting the generalizability of our findings. Finally, because management practices and perspectives can differ considerably across US regions, some heterogeneity in responses is to be expected. Given the small sample size of the present study, we were unable to capture this heterogeneity, and therefore results should be interpreted with this in mind.

CONCLUSIONS

This study provides descriptive and comparative insights into current transportation management practices for replacement heifer, beef-on-dairy, and dairy bull calves across dairy operations, calf haulers, and calf raisers in the United States. Dairy operations reported a difference in age at transport between replacement heifers and beef-on-dairy calves. The willingness of some dairy operation to transport calves in suboptimal condition, along with calf raisers reporting challenges with calf health upon arrival, highlight the need to improve pretransport management, specifically assessing fitness-for-transport. Results from the key stakeholder groups involved also highlight the need for best practice recommendations and increased communication and collaboration between dairies and calf raisers. This newfound knowledge can be used to guide future improvements in calf transport and management strategies to support calf health and welfare as well as industry sustainability.

NOTES

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Nonstandard abbreviations used: CCQA = Calf Care Quality Assurance; CSU = Colorado State University; DCHA = Dairy Calf and Heifer Association; NSAID = nonsteroidal anti-inflammatory drugs; QA = quality assurance; reCAPTCHA = Google's Completely Automated Public Turing Test to tell Computers and Humans Apart.

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