Journal
California Agriculture, 0(0)

ISSN
0008-0845

Authors
Chigerwe, Munashe
Laurence, Hannah M.
Rayburn, Maire C.
et al.

Publication Date
2024-06-30

DOI
10.3733/001c.120614

RESEARCH ARTICLE

Promoting higher levels of immunity from colostrum among calves on organic dairy farms

Calves raised on organic dairy farms achieve lower levels of immunity from colostrum compared to those raised on conventional farms.

by Munashe Chigerwe, Hannah M. Laurence, Maire C. Rayburn and Betsy M. Karle

Online: https://doi.org/10.3733/001c.120614 | An ADA compliant version of this document will be made available as part of the published issue.

Abstract

Colostrum feeding provides immunoglobulins, in a process called transfer of passive immunity, which is critical for dairy calf health and welfare. However, failure of transfer of passive immunity (FTPI) occurs in about 12% of calves nationwide. This study compares the prevalence of FTPI between calves raised on organic and conventional dairy farms, describes the colostral management practices on organic dairy farms in California, and recommends improvements. We compared serum immunoglobulin G (IgG) concentrations between calves raised on organic and conventional dairies and found that the odds of FTPI in calves raised in organic dairies were 2.5 times greater than in calves raised in conventional dairies. Focusing on varied practices in organic dairies, FTPI was 2.9 times more likely in calves fed less than 4 liters of colostrum within the first 24 hours, compared to calves fed more than that amount. We also found that organic dairy producers did not routinely monitor colostral IgG concentrations and passive immunity status. We recommend that organic dairy farmers adopt these practices to decrease the prevalence of FTPI in calves.

Colostrum feeding management practices are critical for dairy calf health and welfare. Acquisition of adequate passive immunity by calves depends on the absorption of at least 150 to 200 grams (g) of colostral immunoglobulin G (IgG) (Chigerwe et al. 2008a). Factors affecting the level of immunity conferred by passively derived colostral immunoglobulins include dam parity (number of lactations), colostral IgG concentration, calf age, volume fed, timing of colostrum collection, weight of first milking colostrum, feeding method, and pooling of colostrum (Chigerwe et al. 2008a; Godden et al. 2019; McGuirk and Collins 2004; Weaver et al. 2000). Failure of transfer of passive immunity (FTPI) in dairy calves can result in increased preweaning morbidity (Donovan et al. 1998; Raboisson et al. 2016) and mortality (Raboisson et al. 2016; Robinson et al. 1988), increased duration of disease (Paré et al. 1993), increased pathogen shedding (Lopez et al. 1998), reduced growth (Furman-Fratczak et al. 2011; Williams et al. 2014), reduced milk production in the first lactation, and increased culling rates (DeNise et al. 1989; Faber et al. 2005).

Bottles of colostrum stored in a freezer at –200°C. The authors' results suggest that organic dairy farms were less likely to heat treat colostrum or check the quality of colostrum before feeding to the calves. *Photo*: Munashe Chigerwe.

In California, the average milk production per cow per year on conventional and organic dairies is estimated at 11,000 kilograms (kg) and 7,000 kg, respectively (Sumner et al. 2019). When compared to conventional dairies across the United States, organic dairy herd sizes are smaller (82 versus 156 cows), produce 30% less milk, are more likely to use unpaid labor, use more pasture-based feeding, and incur higher total economic costs (McBride et al. 2009). While organic herd sizes in California tend to be larger than the national average for organic dairies, and earn a higher milk revenue per hundredweight sold, they incur higher feed, labor, and replacement costs than conventional dairies (Sumner et al. 2019).

Calves nursing milk from a nipple bottle. *Photo*: Munashe Chigerwe.

Previous studies on FTPI in both types of dairy operations across the United States reported a prevalence of 12.1% (Shivley et al. 2018) to 19.2% (Beam et al. 2009). In contrast, the prevalence in Norwegian and Swedish organic dairies was reportedly 31% (Johnsen et al. 2019). However, limited information is available about the status of FTPI in organic versus conventional dairies in the United States. Anecdotal evidence suggests that, due to decreased labor availability on organic farms, the frequency of feeding colostrum to calves using a nipple bottle or allowing nursing from the dam for 24 to 72 hours is higher in organic compared to conventional dairies. In contrast, conventional dairies frequently use oroesophageal intubation (tube feeding), a timely and efficient method, to feed colostrum to calves. Furthermore, organic dairies less frequently heat-treat colostrum before feeding. Heat treatment of colostrum reduces bacteria load and improves absorption of colostrum immunoglobulins (Godden et al. 2019).

We hypothesized that calves raised on organic dairies in California might have a higher prevalence of FTPI than those raised on conventional dairies. This cross-sectional study compares the prevalence of FTPI between calves raised on organic and conventional dairy farms, describes colostral management practices on organic dairy farms, and recommends greater attention to assessment of colostrum management on organic farms.

Dairies sampled throughout state

A cross-sectional study was performed with a convenience sample of calves raised on conventional dairies in Madera, Merced, and Stanislaus counties and organic dairies in Butte, Glenn, Mendocino, and Sonoma counties. Median herd size for organic was 230 cows (ranging from 30 to 1,000). Median herd size for conventional dairies was 1,900 (ranging from 1,400 to 3,500). Because all the conventional dairies in our study were large, we are aware that herd size could have different effects on immunity, and we note this as a caution in interpreting the results.

All conventional dairies were composed of Holstein cows. Of the organic dairies, eight raised Holsteins, and two raised Jersey and Jersey crossbreed cows. The dry-off period (when the cow is pregnant and not lactating) ranged from 2 to 2.5 months for conventional dairies and 2 to 4 months for organic dairies.

The sample size was calculated using JMP software (SAS Institute, Cary, North Carolina). The sample size was based on detecting a minimum IgG concentration of at least 235 milligrams (mg)/deciliter (dL) between calves raised in organic and conventional dairies, the 12.1% current national prevalence of FTPI (Shivley et al. 2018), type 1 error = 5%, power = 80%, and a magnitude of error of 0.1. The 235 mg/dL was based on the IgG concentration in calves before ingestion of colostrum (Chigerwe et al. 2008b). The minimum sample required was 320 calves (160 calves in each system). Two hundred forty-four blood samples from 10 organic dairies and 299 samples from 22 conventional dairies were collected. Holstein calves (222) were overrepresented in the sample population compared to Jersey or Jersey crosses (22).

Surveying organic practices

During the farm visits to organic dairies, calf caretakers verbally responded to a survey questionnaire regarding colostrum management practices, including colostral quality assessment, method of feeding, assessment of passive transfer status in calves, number of calves born per year, frequency of veterinary visits to assess calf health, and frequency and causes of calf morbidity and mortality. Because the focus of this study is to evaluate colostrum management practices in organic dairies, the questionnaire was only administered to organic dairies.

Analyzing blood samples

During farm visits, the investigators collected blood (10 milliliters [mL]) from the jugular vein of 2- to 10-day-old heifer calves in tubes without anticoagulant. The age range of 2 to 10 days was chosen, consistent with a previous study (Elsohaby et al. 2015). At least seven calves were sampled from each farm. Serum total protein (STP) was determined using a hand-held optic refractometer. This method is a farm-adaptable test to estimate IgG concentrations. Serum samples were then stored at −20°C until IgG concentrations were determined by radial immunodiffusion, the reference method, according to the manufacturer's recommendations (Triple J Farms, Bellingham, Washington).

Determination of FTPI was based on two endpoints: less than 1,000 mg/dL (Besser et al. 1991; Furman-Fratczak et al. 2011) and more than 2,001 mg/dL (Chigerwe et al. 2015). A recent review recommended a goal of at least 40% of calves in the excellent range (≥ 2,500 mg/dL), 30% in the good range (1,800–2,490 mg/dL), 20% in the fair range (1,000–17,900 mg/dL), and less than 10% in the poor range (< 1,000 mg/dL) of serum IgG concentration categories (Lombard et al. 2020). In our study, the < 2,001 mg/dL cut-off was considered to appropriately define FTPI if the farm had optimal colostral feeding practices (Chigerwe et al. 2015). The < 1,001 mg/dL cut-off appropriately defined FTPI if the farm had fair colostrum feeding practices (Chigerwe et al. 2015; Lombard et al. 2020).

Mean ± SEM is reported when data were normally distributed, whereas median (95% confidence interval) is reported for non-normally distributed data. Responses from the survey questionnaire are organized and reported. Descriptive statistics of serum IgG concentrations and STP concentrations are reported. The calf was used as the unit of analysis to calculate the prevalence of FTPI. The crude prevalence of FTPI with a 95% confidence interval (95% CI) was calculated based on serum IgG concentrations. The crude prevalence was calculated by dividing the number of calves with FTPI by the number of calves enrolled in each system (organic or conventional).

Using the two cut-off points (< 1,000 mg/dL and < 2,001 mg/dL), two mixed-effects logistic regression models predicting the odds ratio of calves with FTPI between organic and conventional dairies were performed. In the models, management type (conventional or organic), breed (Holstein or Jersey), and herd size (small herd ≤ 250 or large herd > 250 milking cows) (Karle et al. 2019) were considered fixed effects, whereas the individual farm was considered a random effect.

A third mixed-effects logistic regression model was also performed to predict the odds of FTPI (serum IgG concentrations < 1,000 mg/dL) as a function of colostral management variables in organic dairies. Colostrum pooling (yes or no), heat treatment of colostrum (yes or no), use of colostrum replacers (yes or no), calf age at first colostrum feeding (≤ 2 hours, 3 to 6 hours or > 6 hours), method of colostrum feeding (nursing from the dam, bottle-fed, oroesophageal intubation, or a combination of nursing and bottle feeding), and the total volume of colostrum fed within 24 hours (at least 4 liters [L] versus a lower amount) were considered predictor variables. Farm-level variables, including breed and herd size, were considered fixed effects in the logistic regression models. The individual farm was considered a random effect. Colostrum management variables considered fixed effects were calf age at first colostrum feeding, colostrum pooling, heat treatment of colostrum, method of colostrum feeding, the total volume fed within 24 hours of age, and use of colostrum replacers. JMP Pro software (SAS Institute, Cary, North Carolina) was used to perform all analyses.

Pouring colostrum into a pasteurizer for heat treatment before feeding calves. The researchers found that organic dairies were less likely than conventional dairies to heat-treat colostrum before feeding calves. *Photo*: Munashe Chigerwe.

Organic dairy producers should consider assessing colostral immunoglobulin G concentrations and passive immunity status in calves.

Less monitoring on organic farms

Organic dairy farms did not assess colostrum quality on eight of the 10 farms evaluated. Of the farms that assessed colostrum quality, a hydrometer was used on one farm, and visual inspection (colostrum thickness and color) was used on the other. Colostrum from an individual calf's dam was fed on eight farms; one farm fed pooled colostrum, and one fed calves a combination of pooled colostrum and colostrum from their dams. Only one of 10 farms heat-treated colostrum. Colostrum was fed by the bottle on six farms; two allowed calves to nurse for 48 to 72 hours after birth; one farm fed colostrum by oroesophageal intubation; and one farm fed colostrum by the bottle but also allowed calves to nurse for 24 hours. The total volume of colostrum fed by oroesophageal intubation or bottle ranged from 4 to 6 liters within the first 24 hours of life. None of the organic dairy farms fed colostrum replacements or colostrum supplements because of the perception of the unavailability of organic-certified products. None of the farms assessed the passive transfer status of calves. The number of calf neonatal health veterinary visits ranged from zero to 10 per year. Although individual calf records contained minimal information, the morbidity for calves self-reported by producers ranged from 10% to 25%, and mortality ranged from 1% to 10%. Causes of mortality were not investigated or recorded on any of the organic dairy farms. All farms reported that calves were treated with antimicrobials and excluded from the organic herd when necessary.

More FTPI in organic dairies

Serum IgG and STP concentrations for all calves are summarized in table 1. Median (95% CI) serum IgG concentrations for organic and conventional dairies were 2,199 (1,902, 2,491) and 2,456 (2,337, 2,597) mg/dL, respectively. The median (95% CI) for STP concentrations for organic and conventional dairies were 5.8 (5.6, 6.0) and 5.8 (5.6, 5.9) g/dL, respectively.

Using the < 1,000 mg/dL cut-off point, the prevalence of FTPI in calves was 20.5% (50/244; 95% CI, 15.9, 26.0) and 10.4% (31/299; 95% CI, 7.4, 14.4) for organic and conventional dairies, respectively. At the 1,000 mg/dL cut-off point, the odds of FTPI in calves raised on organic dairies were 2.5 times greater (odds ratio = 2.5; 95% CI, 1.5, 4.3; $P = 0.0008$) than in calves raised on conventional dairies. At the 1,000 mg/dL cut-off point, herd size ($P = 0.835$) and breed ($P = 0.115$) were not significant predictors of FTPI. All *P*-values were > 0.05 for all farms when the farm was entered as a random effect in the logistic regression model.

Using the < 2,001 mg/dL cut-off point, the prevalence of FTPI was 45.1% (110/244; 95% CI, 39.0, 51.4) and 35.2% (105/299; 95% CI, 30.2, 41.0) mg/dL for organic and conventional dairies, respectively. At the < 2,001 mg/dL cut-off point, the odds of FTPI in calves raised on organic dairies was 2.3 times greater (odds ratio = 2.3; 95% CI, 1.5, 3.4; $P < 0.0001$) than in calves raised on conventional dairies. At the < 2,001 mg/dL cut-off point, herd size ($P = 0.0006$) was a significant predictor of FTPI, whereas breed ($P = 0.272$) was not a significant predictor of FTPI. All *P*-values were > 0.05 for all farms when the farm was entered as a random effect in the logistic regression model.

Seventeen calves were excluded from the logistic regression analysis because they only nursed colostrum from the dam. Therefore, the time to first feeding and the volume of colostrum consumed could not be accurately determined. Colostrum pooling ($P = 0.379$) and herd size ($P = 0.683$) were not predictors of FTPI. Farm ($P > 0.05$ for all farms) had no significant effect on the odds of FTPI. Method of colostrum administration ($P = 0.029$) and volume of colostrum administered were significant ($P = 0.047$) predictors of FTPI. In contrast, breed, calf age at first feeding, and heat treatment of

TABLE 1. Comparison of STP and serum IgG concentration categories for calves raised on organic and conventional dairy farms

Category and range	Organic dairies % (N)	Conventional dairies % (N)
STP concentrations (g/dL)		
< 5.2	29 (70)[a]	21 (64)[a]
5.2–5.7	15 (37)[b]	24 (73)[c]
5.8–6.3	17 (42)[d]	30 (87)[d]
> 6.3	39 (95)[e]	25 (75)[f]
Serum IgG concentrations (mg/dL)		
< 1000	21 (50)[a]	10 (31)[b]
1001–1500	13 (31)[c]	10 (28)[c]
1501–2000	12 (29)[d]	15 (46)[d]
> 2001	54 (134)[e]	65 (194)[f]
Total	244	299

IgG = immunoglobulin G, STP = serum total protein.
Rows with different letter superscripts are different ($P < 0.05$).

colostrum were not significant predictors of FTPI ($P > 0.05$). The odds for FTPI in calves fed 4 liters or less of colostrum by the bottle or oroesophageal intubation alone was 2.9 times (odds ratio = 2.9; 95% CI, range of 1.5 to 5.7) greater than calves that were fed more than 4 liters of colostrum by the bottle and also were allowed to nurse from the dam.

Colostrum recommendations

Consistent with our hypothesis, the prevalence of FTPI in calves raised on organic dairies (20.5%) was higher than in calves raised on conventional dairies (10.4%). In our study, the prevalence of FTPI in calves raised on organic dairies was lower than in a previous study that reported 31% (Johnsen et al. 2019) when a cut-off point of < 1,000 mg/dL was used to define FTPI. Interestingly, the prevalence of FTPI in calves raised on organic dairies in our study is consistent with the FTPI prevalence estimate reported in a U.S. national survey (excluding organic dairies) over 10 years ago (Beam et al. 2009). In contrast, our study's prevalence of FTPI in conventional dairies was consistent with a recent national survey of all dairies (organic and conventional), which reported FTPI prevalence of 12.1% (Shivley et al. 2018). The decrease in prevalence of FTPI based on these two cross-sectional studies (Beam et al. 2009; Shivley et al. 2018) and the results of our study suggest that positive improvements in colostral feeding practices over the last decade might be limited to conventional dairies.

When a cut-off point of < 2,001 mg/dL was used to define FTPI in calves, the prevalence of FTPI was very high for calves raised on both organic (45.1%) and conventional (35.2%) dairies. This suggests that the cut-off point of < 2,001 mg/dL for defining FTPI might not be appropriate in our study because we did not determine optimal cut-off points specific for organic dairies or determine colostral feeding practices in conventional dairies.

In our study, the proportion of calves in the poor serum IgG concentrations category from conventional dairies (10%) was consistent with recommendations by Lombard and others (Lombard et al. 2020), discussed above. In contrast, the proportion of calves in the poor serum IgG concentrations category from organic dairies was higher (21%) than recommended.

The total volume of colostrum fed within 24 hours was associated with FTPI in calves raised on organic dairies, with 4 liters or less associated with a higher probability of FTPI, compared to more than 4 liters. Previous studies indicated that mean serum IgG concentrations at 24 hours were significantly higher for calves fed 4 liters of colostrum at 0 hours and an additional 2 liters at 12 hours, compared with calves fed only 2 liters of high-quality colostrum at 0 hours and an additional 2 liters at 12 hours (Morin et al. 1997). This might suggest that calves in our study that were fed more than 4 liters of colostrum were likely to have consumed the recommended dose of at least 150 to 200 grams of IgG. In a nationwide U.S. study, 60% of maternal colostrum had concentrations lower than the recommended industry standards, with colostrum samples from Arizona, California, and Texas recording the lowest colostral IgG concentrations (Morill et al. 2012).

The age of the calf at first colostrum feeding was not a significant variable predicting FTPI in our study. This contrasts with previous studies indicating that calves fed colostrum at ≤ 6 hours were at lower risk for FTPI than calves older than 6 hours (Fischer et al. 2018). A possible reason for this difference is the lack of precise individual calf age at first colostrum feeding in our study. Calves who were both fed colostrum by the bottle and allowed to nurse from dams within 24 hours after birth were likely to achieve adequate transfer of passive immunity because they ingested at least 4 liters of colostrum.

Responses from the survey questionnaire indicated that organic dairies fed colostrum by oroesophageal intubation or nipple bottle or allowed calves to nurse. Based on the responses from the survey, the majority of organic dairies did not routinely check the quality of colostrum before feeding, use colostrum replacers, or check for passive transfer status in calves. Furthermore, organic dairies did not have frequent veterinary calf health visits or detailed preweaning morbidity and mortality calf records. The lack of frequent veterinary visits in our study was consistent with previous studies indicating that organic dairies were associated with less frequent veterinary usage (Richert et al. 2013).

The findings in our study suggest that organic dairies should consider increased assessment of colostrum quality and passive transfer status in calves raised on organic dairies. In particular, organic dairy producers should consider affordable tests for assessing colostrum and monitoring passive transfer status in calves, such as refractometry (Quigley et al. 2013), as a management strategy to monitor and reduce FTPI. Furthermore, organic dairies should consider improving record keeping during the calf period, including morbidity and mortality events for calves.

A limitation of our study is that farms were not randomly selected; thus, the results have limited external validity. Although the individual farm was included as a random effect in the analysis, all organic dairies in our study were in Northern California. In contrast, all conventional dairies were in the Central Valley, consistent with the distribution of dairy farms in California. Thus, the geographical location might have an impact on colostrum management. The number of conventional dairies enrolled in the study was higher than the number of organic dairies. Therefore, the information on colostrum management practices in organic dairies might not be representative. Further, colostral IgG concentrations were not determined; therefore, the effect of colostral IgG concentrations on FTPI could not be assessed. The survey questionnaire responses were self-reported and therefore prone to response bias.

Because the focus of our study was to compare the prevalence of FTPI between organic and conventional dairies and further assess the colostrum-feeding practices on organic dairies to fill a knowledge gap, we did not evaluate colostrum feeding practices on conventional dairies. While this is another limitation of our study, conventional practices have been described in several studies. Consequently, studies comparing colostrum management practices between organic and conventional dairies should be considered. Further studies on colostrum quality assessments, passive transfer status assessments, and morbidity and mortality events attributable to FTPI in calves raised on organic dairies are warranted.

In summary, because the odds of FTPI in calves raised on organic dairies were twice as high as those raised on conventional dairies, organic dairy producers should consider assessing colostral IgG concentrations and passive immunity status in calves to monitor and reduce FTPI. CA

M. Chigerwe is Professor of Livestock Medicine and Surgery, Department of Medicine and Epidemiology, UC Davis School of Veterinary Medicine; H.M. Laurence is Resident and Graduate Student, Colorado State University; M.C. Rayburn is Staff Research Assistant, Department of Pediatrics, School of Medicine, Stanford University; B.M. Karle is Dairy Advisor, UC Cooperative Extension, Glenn County.

We thank the National Institute of Food and Agriculture (NIFA) for funding this research (#CALV-AH-342). Funding for Hannah Laurence was provided by the University of California Davis School of Veterinary Medicine Student Training in Advanced Research (STAR) program.

References

Beam AL, Lombard JE, Kopral CA, et al. 2009. Prevalence of failure of passive transfer of immunity in newborn heifer calves and associated management practices on U.S. dairy operations. J Dairy Sci 92(8):3973–80. https://doi.org/10.3168/jds.2009-2225

Besser TE, Gay CC, Prichett L. 1991. Comparison of three methods of feeding colostrum to dairy calves. J Am Vet Med Assoc 198(3):419–22. https://doi.org/10.2460/javma.1991.198.03.419

Chigerwe M, Tyler JW, Schultz LG, et al. 2008a. Effect of colostrum administration by use of oroesophageal intubation on serum IgG concentrations in Holstein bull calves. Am J Vet Res 69(9):1158–63. https://doi.org/10.2460/ajvr.69.6.791

Chigerwe M, Tyler JW, Nagy DW, et al. 2008b. Frequency of detectable serum IgG concentrations in precolostral calves. Am J Vet Res 69(6):791–5. https://doi.org/10.2460/ajvr.69.6.791

Chigerwe M, Hagey JV, Aly SS. 2015. Determination of neonatal serum immunoglobulin G concentrations associated with mortality during the first 4 months of life in dairy heifer calves. J Dairy Res 82(4):400–6. https://doi.org/10.1017/S0022029915000503

DeNise SK, Robison JD, Stott GH. 1989. Effects of passive immunity on subsequent production in dairy heifers. J Dairy Sci 72(2):552–4. https://doi.org/10.3168/jds.S0022-0302(89)79140-2

Donovan GA, Dohoo IR, Montgomery DM, et al. 1998. Associations between passive immunity and morbidity and mortality in dairy heifers in Florida, USA. Prev Vet Med 34(1):31–46. https://doi.org/10.1016/S0167-5877(97)00060-3

Elsohaby I, McClure TJ, Keefe GF. 2015. Evaluation of digital and optical refractometers for assessing failure of transfer of passive immunity in dairy calves. J Vet Intern Med 29(2):721–6. https://doi.org/10.1111/jvim.12560

Faber SN, Faber NE, McCauley TC, Ax RL. 2005. Case study: Effects of colostrum ingestion on lactational performance 1. Prof Anim Sci 21(5):420–5. https://doi.org/10.15232/S1080-7446(15)31240-7

Fischer AJ, Song Y, He Z, et al. 2018. Effect of delaying colostrum feeding on passive transfer and intestinal bacterial colonization in neonatal male Holstein calves. J Dairy Sci 101(4):3099–109. https://doi.org/10.3168/jds.2017-13397

Furman-Fratczak K, Rzasa A, Stefaniak T. 2011. The influence of colostral immunoglobulin concentration in heifer calves' serum on their health and growth. J Dairy Sci 94(11):5536–43. https://doi.org/10.3168/jds.2010-3253

Godden S, Lombard JE, Woolums AR. 2019. Colostrum management for dairy calves. Vet Clin N Am–Food A 35(3):535–56. https://doi.org/10.1016/j.cvfa.2019.07.005

Johnsen JF, Viljugrein H, Bøe KE, et al. 2019. A cross-sectional study of suckling calves' passive immunity and associations with management routines to ensure colostrum intake on organic dairy farms. Acta Vet Scand 61(1):7. https://doi.org/10.1186/s13028-019-0442-8

Karle BM, Maier GU, Love WJ, et al. 2019. Regional management practices and prevalence of bovine respiratory disease in California's preweaned dairy calves. J Dairy Sci 102(8):7583–96. https://doi.org/10.3168/jds.2018-14775

Lombard J, Urie N, Garry F, Godden S, et al. 2020. Consensus recommendations on calf- and herd-level passive immunity in dairy calves in the United States. J Dairy Sci 103(8):7611–24. https://doi.org/10.3168/jds.2019-17955

Lopez JW, Allen SD, Mitchell J, et al. 1998. Rotavirus and Cryptosporidium shedding in dairy calf feces and its relationship to colostrum immune transfer. J Dairy Sci 71(5):1288–94. https://doi.org/10.3168/jds.S0022-0302(88)79685-X

McBride WD, Greene C. 2009. Characteristics, Costs, and Issues for Organic Dairy Farming. ERR-82. U.S. Department of Agriculture, Economic Research Service. www.ers.usda.gov/publications/pub-details/?pubid=46268 (accessed Nov. 29, 2021).

McGuirk SM, Collins M. 2004. Managing the production, storage, and delivery of colostrum. Vet Clin N Am–Food A 20(3):593–603. https://doi.org/10.1016/j.cvfa.2004.06.005

Morin DE, McCoy GC, Hurley WL. 1997. Effects of quality, quantity, and timing of colostrum feeding and addition of a dried colostrum supplement on immunoglobulin G1 absorption in Holstein bull calves. J Dairy Sci 80(4):747–53. https://doi.org/10.3168/jds.S0022-0302(97)75994-0

Morrill KM, Conrad E, Lago A, et al. 2012. Nationwide evaluation of quality and composition of colostrum on dairy farms in the United States. J Dairy Sci 95(7):3997–4005. https://doi.org/10.3168/jds.2011-5174

Paré J, Thurmond MC, Gardner IA, Picanso, JP. 1993. Effect of birthweight, total protein, serum IgG and packed cell volume on risk of neonatal diarrhea in calves on two California dairies. Can J Vet Res 57(4):241–6.

Quigley JD, Lago A, Chapman C, et al. 2013. Evaluation of the Brix refractometer to estimate immunoglobulin G concentration in bovine colostrum. J Dairy Sci 96(2):1148–55. https://doi.org/10.3168/jds.2012-5823

Raboisson D, Trillat P, Cahuzac C. 2016. Failure of passive immune transfer in calves: A meta-analysis on the consequences and assessment of the economic impact. PLoS One 11(3):e0150452. https://doi.org/10.1371/journal.pone.0150452

Richert RM, Cicconi KM, Gamroth MJ, et al. 2013. Management factors associated with veterinary usage by organic and conventional dairy farms. JAVMA–J Am Vet Med A 242(12):1732–43. https://doi.org/10.2460/javma.242.12.1732

Robinson JD, Stott GH, DeNise SK. 1988. Effects of passive immunity on growth and survival in the dairy heifer. J Dairy Sci 71(5):1283–7. https://doi.org/10.3168/jds.S0022-0302(88)79684-8

Shivley CB, Lombard JE, Urie NJ, et al. 2018. Preweaned heifer management on U.S. dairy operations: Part II. Factors associated with colostrum quality and passive transfer status of dairy heifer calves. J. Dairy Sci 101(10):9185–98. https://doi.org/10.3168/jds.2017-14008

Sumner DA, Messina DR, Valdes-Donoso P. 2019. Organic dairy: Economic opportunities and challenges with a focus on California. Organic Farmer 3(2):10–14. https://cail.ucdavis.edu/2019/07/17/organic-dairy-economic-opportunities-and-challenges-with-a-focus-on-california/ (accessed Nov. 29, 2021).

Weaver DM, Tyler JW, VanMetre DC, et al. 2000. Passive transfer of colostral immunoglobulins in calves. J Vet Intern Med 14(6):569–77. https://doi.org/10.1111/j.1939-1676.2000.tb02278.x

Williams DR, Pithua P, Garcia A, et al. 2014. Effect of three colostrum diets on passive transfer of immunity and preweaning health in calves on a California dairy following colostrum management training. Vet Med Int 2014: Article ID 698741. https://doi.org/10.1155/2014/698741