A survey of northern Victorian dairy farmers to investigate dairy calf management: colostrum feeding and management

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Objectives To describe colostrum management practices carried out in northern Victorian dairy herds and to identify weaknesses in these areas that may affect calf health and welfare by comparing the results with the current industry recommendations

Methods A questionnaire to obtain information about colostrum management and calf-rearing practices was sent to commercial dairy farming clients of Rochester Veterinary Practice between June and September 2013. The questionnaire consisted of a general herd overview and colostrum harvesting practices.

Results The response rate was 39% (58/150). Many dairy producers were not meeting the current industry recommendations in the following areas: (1) time of removal calf from the dam, (2) relying on calf suckling colostrum from the dam to achieve adequate passive transfer, (3) failing to supplement calves with colostrum, (4) feeding inadequate volumes of colostrum, (5) delayed colostrum harvesting, (6) pooling of colostrum, (7) failing to objectively assess colostrum quality or relying on visual assessment and (8) storing colostrum for a prolonged periods of time at ambient temperatures.

Conclusion The results from this survey highlight the need for greater awareness of industry standards for colostrum management and feeding hygiene.

Keywords calf management; colostrum; dairy cattle; industry standards

Abbreviations CI, confidence interval; cfu, colony-forming units; FTPI, failure of transfer of passive immunity; IgG, immunoglobulin G

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Calves are required to ingest colostrum from the dam and absorb immunoglobulins (especially IgG) across the intestinal epithelium, because the syndesmochorial placentation in the cow prevents transmission of immunoglobulins to the fetus in utero.[1] As a consequence, neonatal calves are hypogammaglobulinaemic or agammaglobulinaemic at birth.[2] It is essential that calves ingest and absorb adequate amounts of colostrum within the first 24 h of life, as after this point the uptake of macromolecules, such as IgG, ceases. [3]

Dairy farming under northern Victorian conditions relies on the practice of removing the calves from the dam within the first few days of life and artificially rearing the calves.[4] Many calves are removed from the calving area only once daily and they may or may not receive colostrum supplementation after removal from the dam.[4]

The aim of supplementation is to reduce the risk of failure of transfer of passive immunity (FTPI). The term FTPI is used when the calf's serum IgG concentration is < 10 mg/mL at 24–48 h of age.

Several factors aid in successful transfer of immunity, including feeding enough colostrum with a high concentration of immunoglobulins (> 50 mg/mL of IgG), feeding the colostrum within 12–24 h of birth and reducing bacterial contamination of the colostrum being fed.[2,5,6] Serum concentrations of IgG > 10 mg/mL at 24–48 h after birth indicate that adequate passive transfer of immunity has occurred and are associated with a significantly reduced risk of morbidity and mortality in the preweaning period.[7,8] Successful passive transfer has also been recognised to provide many longer term benefits, including reduced morbidity and mortality rates post-weaning, improved feed efficiency, improved weight gain, reduced age at first calving, improved milk production in future lactations and a reduced risk of being culled in the first lactation period.[2,9,10]

There are few colostrum management studies conducted under Australian conditions. Vogels et al. reported the prevalence of FTPI and agammaglobulinaemia in calves in south-west Victoria to be 38% and 8%, respectively.[4] Those authors also explored potential risk factors for both FTPI and agammaglobulinaemia and found that breed of the calf and the rate of removing calves from the calving area affected the levels of FTPI and agammaglobulinaemia in calves.[4] More recently, we reported on the risk factors that affected colostrum quality in northern Victorian dairy cows.[11] Although a number of colostrum management and feeding practices were examined in those studies, other aspects of colostrum hygiene, colostrum storage practices and management of dry cows leading up to calving were not examined.

Limited data are available on the common colostrum feeding and management practices carried out on dairy farms in Australia, which makes it difficult to establish how well current scientific recommendations are integrated into on-farm practices. The objectives of this survey were to firstly describe colostrum feeding and management practices carried out in northern Victorian dairy herds and secondly, to identify areas of current colostrum feeding and management that may affect calf health and welfare by comparing the results with the current industry recommendations.

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Materials and methods

A questionnaire designed to investigate colostrum management and calf-rearing practices was sent via mail to all 150 commercial dairy farming clients serviced by Rochester Veterinary Clinic between June and September 2013. The questionnaires were returned by mail or by collection on farm during routine veterinary visits.

The questionnaire had 60 questions and was divided into three sections containing 17, 25 and 18 questions, respectively.

Section 1 focussed on herd description with questions designed to capture general farm details, such as milking herd size, size of land farmed, cow breed composition of the herd, milk production (L/cow/year) and replacement heifer rates, and to explore common practices on these farms, such as calving pattern and grain/supplement usage (tonnes/cow/year).

Questions in Section 2 focussed on colostrum harvesting and management, including colostrum storage, hygiene and feeding practices carried out on farm.

In Section 3, calf-rearing and management, including calf-rearing routines such as housing arrangements, feeding regime and husbandry practices, were explored and the results are presented in a separate paper.[12]

All returned questionnaires were individually examined and the data were recorded in Microsoft Excel 2010 (Microsoft Corp., Redmond, WA, USA). Descriptive statistics were calculated using IBM SPSS Statistics 2013 for Windows, Version 22.0 (IBM Corp., Armonk, NY, USA).

The results were compared to current Australian and international industry recommendations.[5,13,14]

Each variable in the survey was defined as not meeting the current industry recommendations if ≥ 25% of respondents were not meeting the industry recommendation.

Results

A total of 58 of 150 (39%) questionnaires were returned. The average farm size (mean ± standard deviation, SD) was 263.41 (± 376.18) ha with an average of 267 (± 164) cows per farm. Each farm surveyed produced an average of 7166.47 (± 1082.94) L of milk per year, retained 26.26 (± 15)% of heifers and had a grain/supplement usage of 1.96 (± 0.51) tonnes/cow/year. Herd descriptive data are summarised in Table 1, with the most common dairy herd composition consisting of Holstein-Friesian and crossbred cows, and the most common calving pattern being split. The animal health practices and the precalving dry cow and heifer management are outlined in Table 2.

The common practices of timing of calf removal from the dam, supplementation of colostrum and colostrum management, including harvesting and measuring quality, are outlined in Table 3. Of the surveyed herds > 89.7% (95% confidence interval (CI) 79.2–95.2) had calves removed from their dams > 2 h postpartum and over one-third (> 35.7%) were fed their first colostrum > 2 h postpartum. Approximately one-quarter (25.9%) of respondents indicated that they relied on the calf suckling colostrum from the dam to achieve adequate passive transfer, while a majority indicated that they pooled colostrum (67.2%) and visually assessed colostrum quality (65.5%), with only a small number of herds using a colostrometer (22.4%, 95% CI 13.6–34.7) or a Brix refractometer (6.9%, 95% CI 2.7–16.4) to assess colostrum quality (Table 3). Colostrum was stored at ambient temperatures for an average of 6.14 days (median: 2 days) and refrigerated for an average 5.5 days (median: 3 days), both of these being higher than the industry recommendations (Table 4).

Table 1. Dairy breed composition and calving pattern of 58 northern Victorian dairy farms

Item	Category	n (%)	95% CI
Cow breed	Holstein-Friesian	13 (22.4)	13.6–34.7
	Jersey	5 (8.6)	3.7–18.6
	Holstein-Friesian and Jersey	7 (12.1)	6.0–22.9
	Crossbred[a]	3 (5.2)	1.8–14.1
	Holstein-Friesian and crossbred	14 (24.1)	15.0–36.5
	Holstein-Friesian, Jersey and crossbred	10 (17.2)	9.6–28.9
	Other herd compositions[a]	6 (10.3)	4.8–20.8
Calving pattern	Seasonal (Autumn: Mar–May)	3 (5.2)	1.8–14.1
	Seasonal (Spring: Sept–Nov)	12 (20.7)	12.3–32.8
	Split	37 (63.8)	50.9–74.6
	Batch[b]	4 (6.9)	2.7–16.4
	Year-round	2 (3.4)	1.0–11.7

[a]Combinations of breeds including Holstein-Friesian, Jersey, crossbred, Illawarra Red and Australian Red.
[b]Batch calving defined as calving down cows in more than 3 distinct periods of the year.
CI, confidence interval.

Survey responses to all questions on calf and colostrum management practices in the 58 surveyed northern Victorian dairy farms are summarised in Supplementary Table 1.

Discussion

This study gave some insight into the common colostrum management and calf-rearing practices on northern Victorian dairy farms and highlighted the need for greater awareness of industry standards for colostrum feeding and management. Of particular concern was that some of the herds surveyed did not conform to industry standards pertaining to the collection, assessment and storage of colostrum and in ensuring that calves received adequate, quality colostrum, including failure to supplement calves with colostrum and relying on calf suckling from the dam to achieve adequate passive transfer.

Calf removal from cow

Our study found that a in a large proportion of herds surveyed, removal of the calf from the dam occurred later than the recommended 1–2 h postpartum.[13] Removal of the calf from the dam as soon as possible after birth is reported to reduce calf exposure to

Table 2. Survey responses of 58 northern Victorian dairy herds regarding animal health practices and their precalving dry cow and heifer management

Survey question	Category	Responses n (%)	95% CI
Pregnant cows vaccinated prior to calving[a]	Yes	51 (87.9)	77.1–94.0
	No	7 (12.1)	6.0–22.9
Late pregnant cows fed a transition diet prior to calving[b]	Yes	50 (86.2)	75.1–92.8
	No	8 (13.8)	7.2–24.9
Cows are calved in a	Paddock	51 (87.9)	77.1–94.0
	Calving pad	2 (3.4)	1.0–11.7
	Paddock/calving pad or calving shed	5 (8.6)	3.7–18.6
No. of cows grouped together in calving area	≤ 5	7 (12.1)	6.0–22.9
	6–10	1 (1.7)	0.3–9.1
	> 10	50 (86.2)	75.1–92.8
Heifers calved down with older cows	Yes	38 (65.5)	52.7–76.4
	No	20 (34.5)	23.6–47.3
Duration of heifers being housed with older cows prior to calving	≤ 1 month	22 (37.9)	26.6–50.8
	1–2 months	11 (19)	10.9–30.9
	> 2 months	5 (8.6)	3.7–18.6
	NA	20 (34.5)	23.6–47.3

[a]Cows in the current study were vaccinated against leptospirosis, clostridial disease, *Escherichia coli*, rotavirus and coronavirus.
[b]Transition period defined as 4 weeks before and after calving and efforts to reduce periparturient diseases were made through dietary manipulation.
CI, confidence interval; NA, not applicable.

pathogens within the calving environment and on the integument of the cow[13,14] and reduces the stressful effect of breaking the bond between the cow and calf, as the bond becomes more pronounced the longer the calf remains with the cow.[15] Others have also demonstrated a higher rate of FPTI in calves that received colostrum by natural suckling compared with artificial supplementation.[4,16] One study found that calves that had never been hand fed extra colostrum had three-fold odds of agammaglobulinaemia when compared with calves that were always supplemented with colostrum[4] and Humphris reported that natural suckling failed to provide adequate passive transfer in 42.6% of calves compared with 8.3% in calves that received a single artificial feed of colostrum and 2.4% of that received two artificial feeds of colostrum.[16]

On Australian dairy farms, labour availability largely influences both the timing of calf removal and the number of times per day calves are collected from the calving area. In the current survey, most herds were either removing calves within 12 h (60.3%, 95% CI 47.5–71.9), suggesting twice daily removal, or within 6 h (10.3%, 95% CI 4.8–20.8) suggesting 4 times daily removal, which may reduce the risk of FPTI.[4,13]

Colostrum feeding

Researchers in the USA recommend that calves are removed from the dam within 2 h of birth, prior to the calf suckling, and supplementation with colostrum containing 100–200 g immunoglobulins within the first 4–6 h.[8,13] This practice may be regarded as the 'gold standard' and may be practical on very intensively run dairy farms with adequate labour available, but is unlikely to be practical on most dairy enterprises, where labour is a major limiting factor.

It is likely the above guideline will be difficult to achieve in most Australian dairy herds. However, two-thirds of calves in the current survey received colostrum in the first 6 h of life, which does meet industry recommendations, although it is likely that many calves received their first feed of colostrum by nursing their dam. On average, a calf will only consume 2.5 L of colostrum if left to nurse from the cow. If the dam's colostrum is poor quality, calves will reach satiety before consuming the required level of immunoglobulins, putting the calf at high risk of FPTI.[17]

Method of colostrum supplementation and volume fed to calves

Our results on oesophageal tubing were similar to those in a previous study.[4] Oesophageal tubing has the advantage of ensuring the calf is given the desired volume of colostrum in a short period, when compared with natural suckling. However, anecdotally, oesophageal tubing is viewed by some producers as a challenging procedure to learn and there is a risk of aspiration, and possibly death of the calf, if the procedure is not carried out correctly.

The volume of colostrum supplemented to calves in the current study varied from 1 to ≥4 L, with most farms surveyed offering 2 L, which is also similar to previous findings.[4] These findings likely reflect a set protocol used by a number of herds in northern Victorian and south-west Victoria in order to ensure that all calves receive colostrum. Other herds may only supplement calves suspected of not having nursed from the dam and it is likely that calves from these herds are not receiving adequate volumes of high-quality colostrum, putting them at risk of FTPI.

Table 3. Survey responses of 58 northern Victorian dairy herds regarding calf and colostrum management practices and the current industry recommendations

Survey question	Category	n (%)	95% CI	Industry recommendation/ reference
Age at which the calf is removed from dam (h)	< 6	6 (10.3)	4.8–20.8	< 2[12]
	6–12	29 (50)	37.5–62.5	–
	> 12	23 (39.7)	28.1–52.5	–
Timing of first feed of colostrum (h)	0– 6	37 (63.8)	50.9–75.0	< 2[5]
	7–11	17 (29.3)	19.2–42.0	–
	> 12	4 (6.9)	2.7–16.4	–
Colostrum feeding to calf	Suckle dam	15 (25.9)	16.4–38.4	Not recommended[5,12]
	Oesophageal feeding	5 (8.6)	3.7–18.6	Recommended[5]
	Both	38 (65.5)	52.7–76.4	
If oesophageal feeding, volume of colostrum fed (L)	1	5 (8.6)	3.7–18.6	–
	1–2	27 (46.6)	34.3–59.2	–
	2–3	15 (25.9)	16.4–38.4	–
	> 3	2 (3.4)	1.0–11.7	–
	Not answered	9 (15.5)	8.4–26.9	–
Multiple cows milked into the same bucket (pooling colostrum)	Yes	19 (32.8)	54.4–77.9	–
	No	39 (67.2)	54.4–77.9	Not recommended[5,12]
Method of storing colostrum after harvesting	Frozen	1 (1.7)	0.3–9.1	-
	Refrigerated	5 (8.6)	3.7–18.6	1–2 days[5]
	Ambient temperature	32 (55.2)	42.5–67.3	< 2 h[12]
	Combination of the above	19 (32.8)	22.1–45.6	
Store excess colostrum	Yes	39 (67.2)	54.4–77.9	–
	No	19 (32.8)	54.4–77.9	–
Method of measuring colostrum quality	Colostrometer	13 (22.4)	13.6–34.7	Recommended[13]
	Brix refractometer	4 (6.9)	2.7–16.4	Recommended[13]
	Visually	38 (65.5)	52.7–76.4	Not recommended[13]
	Do not measure quality	3 (5.2)	1.8–14.1	-

CI, confidence interval.

Timing of colostrum harvesting

Our results for cow collection and colostrum harvest are comparable to those of Vogels et al., who found that 71% of farms removed the cows from the calving environment within a day of calving.[4] The timing of cow and calf removal from the calving environment on Australian dairy farms is likely to be influenced by both labour availability and the number of times per day calves are collected from the calving area.

We reported previously that the timing of colostrum harvesting affected colostrum quality, with higher quality colostrum harvested from cows within 12 h of calving compared with colostrum harvested later,[11] suggesting it is best to harvest the colostrum as soon as possible after calving to improve quality.

Pooling of colostrum

Pooling of raw colostrum from multiple cows occurred in approximately one-third of the herds in this study. The practice of pooling raw colostrum is not recommended because it may result in the dilution of high-quality colostrum[2] and increases the risk of spreading or exposing neonatal calves to colostral-borne pathogens such as

Table 4. Descriptive statistics for colostrum storage on 58 northern Victorian dairy herds surveyed and the current industry recommendations

Storage method	Responses (n)	Mean (± SD)	Median	Range (min.–max.)	Industry recommendation
Ambient temperature (days)	43	6.14 (±10.75)	2	1–60	< 2 h[5,12]
Refrigerate (days)	20	5.5 (±5.69)	3	2–14	1–2[5]
Frozen (months)	16	6 (±0)	6	6–6	12[5]

Johne's disease pathogen (*Mycobacterium avium* subsp. *paratuberculosis*), *Salmonella* spp. or *Escherichia coli*.[5,13]

Assessing colostrum quality

Assessment of colostrum quality was carried out in most the herds (94.8%, 95% CI 85.9–98.2) in our study. The most common method for assessing colostrum quality was visual assessment, which may identify obviously watery, bloody or discoloured colostrum.[5] However, visual assessment is not a reliable method of assessing colostrum quality.[18] More reliable on-farm methods for measuring colostrum quality include the use of colostrometers and Brix refractometers. Colostrometers have high specificity, but low sensitivity, resulting in samples being falsely classified as high quality. There are several factors such as fat content, other solids and temperature that may also affect colostrometer readings.[19,20] The Brix refractometer provides an acceptable estimate of IgG in first-milking bovine colostrum and can be easily carried out cow-side.[21] A potential limitation to using a Brix refractometer to measure colostrum quality is that colostrum with a high fat content may result in a wide band of colour transitioning (from blue to white) when reading the Brix refractometer.[21]

Although both the Brix refractometer and colostrometer have their limitations, they both are rapid and low-cost cow-side tests that may be useful for differentiating low-quality and high-quality colostrum. The survey identified a need for improved uptake of simple tools to aid in assessing colostrum quality on farm.

Colostrum storage

Storage of excess colostrum was carried out in over two-thirds of the herds surveyed, with the most common method being storage at ambient/room temperature for a higher than expected duration (mean: 6.14 days). There was a large range of storage times, with a maximum of 60 days, indicating that some respondents may have misinterpreted the question and the time recorded was for the colostrum stored at ambient temperatures and fermented and then fed to calves, not the time that colostrum was stored at ambient temperature and supplemented to calves for the purpose of reducing the risk of FTPI. The median duration of storing colostrum at ambient temperature was 2 days, which is more likely to be a reflection of the colostrum that is used to supplement calves for the purpose of reducing the risk of FTPI.

In the current survey, a majority of the herds where colostrum was stored at ambient temperature was not meeting the industry recommendation of storing colostrum for no more than 1 h[5,13] and consequently, are at risk of supplementing calves with unhygienic colostrum. Total microbial and coliform populations in colostrum stored at warm ambient temperatures can rapidly multiply within 24 h to levels that are above industry recommendations of a total plate count < 100,000 cfu/mL and total coliform count < 10,000 cfu/mL, respectively.[22] Bacteria in the colostrum are believed to bind free IgG in the intestinal lumen or block the uptake and subsequent transport of IgG into the enterocyte,[23–25] affecting the passive transfer of colostral immunoglobulins.[25,26]

Study limitations

This questionnaire was a survey and excluded any time-based implications. As the calving season progresses on each of the farms, practices may vary. In addition, the questionnaire was directed at the herd-level, so the data collected should be regarded as reflecting herd policies, rather than definite events that occur for each individual cow or calf. There is a potential for bias in the respondents, because of their regular use of veterinarians and affiliation with the Rochester Veterinary Practice. The features of non-respondents were not determined. There was the opportunity for misclassification of farmer-reported data in the questionnaire, particularly in regards to colostrum management and feeding. This was difficult to avoid without being present on each of the farms to assess the practices that each herd carried out.

Conclusions

The current survey has provided empirical data of the common colostrum feeding and management practices in northern Victorian dairy herds. The survey identified that improvements were required in a number of herds in the practices of time of removal calf from the dam, relying on calf suckling colostrum from the dam to achieve adequate passive transfer, failing to supplement calves with colostrum, feeding inadequate volumes of colostrum, delayed colostrum harvesting, pooling of colostrum, failing to objectively assess or relying upon visual assessment to determine colostrum quality and storing colostrum for a prolonged period of time at ambient temperatures.

The survey results highlighted the need for further education about colostrum feeding and management. The authors recommend that all dairy producers have a set protocol for supplementing dairy calves with additional high-quality colostrum. This should include all replacement and excess heifer and bull calves. Practising veterinarians can assist in implementing protocols, train producers in the practice of oesophageal feeding of calves and provide advice to dairy producers on current recommendations.

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Conflicts of interest and sources of funding

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References

1. Arthur GH, Nokes DE, Pearson H. *The development of the conceptus: pregnancy and parturition in veterinary reproduction and obstetrics*. 5th edn. Bailliere Tindall, London, 1982.
2. Weaver DM, Tyler JW, Van Metre CD et al. Passive transfer of colostral immunoglobulins in calves. *J Vet Intern Med* 2000;14:569–577.
3. Bush LJ, Staley T. Absorption of colostral immunoglobulins in newborn calves. *J Dairy Sci* 1980;63:672–680.

4. Vogels Z, Chuck G, Morton J. Failure of transfer of passive immunity and agammaglobulinaemia in calves in south-west Victorian dairy herds: prevalence and risk factors. *Aust Vet J* 2013;91:150–158.
5. Godden S. Colostrum management for dairy calves. *Vet Clin North Am Food Anim Pract* 2008;24:19–39.
6. Johnson JL, Godden SM, Molitor T et al. Effects of feeding heat-treated colostrum on passive transfer of immune and nutritional parameters in neonatal dairy calves. *J Dairy Sci* 2007;90:5189–5198.
7. Quigley JD, Drewry JJ. Nutrient and immunity transfer from cow to calf pre- and postcalving. *J Dairy Sci* 1998;81:2779–2790.
8. Wells SJ, Dargatz DA, Ott SL. Factors associated with mortality to 21 days of life in dairy heifers in the United States. *Prev Vet Med* 1996;29:9–19.
9. Faber SN, Faber NE, McCauley TC, Ax RLTC et al. Case study: effects of colostrum ingestion on lactational performance. *Prof Anim Sci* 2005;21:420–425.
10. Donovan GA, Dohoo IR, Montgomery DM et al. Associations between passive immunity and morbidity and mortality in dairy heifers in Florida, USA. *Prev Vet Med* 1998;34:31–46.
11. Phipps AJ, Beggs DS, Murray AJ et al. Factors associated with colostrum immunoglobulin G concentration in northern-Victorian dairy cows. *Aust Vet J* 2017;95:237–243.
12. Phipps AJ, Beggs DS, Murray AJ et al. A survey of northern Victorian dairy farmers to investigate dairy calf management: calf-rearing practices. *Aust Vet J* 2018;96:107–110.
13. McGuirk SM, Collins M. Managing the production, storage, and delivery of colostrum. *Vet Clin North Am Food Anim Pract* 2004;20:593–603.
14. Dairy Australia. Rearing healthy calves: how to raise calves that thrive. *Dairy Australia, Melbourne*, 2011:7–164.
15. Flower FC, Weary DM. Effects of early separation on the dairy cow and calf. 2: separation at 1 day and 2 weeks after birth. *Appl Anim Behav Sci* 2001;70:275–284.
16. Humphris TB. *The effect of natural suckling, compared with natural suckling and artificial supplementation with colostrum, on the level of passive transfer of immunoglobulins in calves*. MVS thesis, University of Melbourne, 1998.
17. Parkinson TJ, Vermunt JJ, Malmo J. Diseases of cattle in Australasia: a comprehensive textbook. *VetLearn, Wellington, New Zealand*, 2010:630.
18. Maunsell FP, Morin DE, Constable PD et al. Use of mammary gland and colostral characteristics for prediction of colostral IgG. 1: concentration and intramammary infection in Holstein cows. *J Am Vet Med Assoc* 1999;214:1817–1823.
19. Edwards RA. A comparison of the hydrometric and gravimetric methods for the determination of solids-not-fat when applied to the milk of individual cows in a single herd. *J Dairy Res* 1961;28:109–115.
20. Mechor G, Gröhn Y, Van Saun R. Effect of temperature on colostrometer readings for estimation of immunoglobulin concentration in bovine colostrum. *J Dairy Sci* 1991;74:3940–3943.
21. Bielmann V, Gillan J, Perkins NR et al. An evaluation of Brix refractometry instruments for measurement of colostrum quality in dairy cattle. *J Dairy Sci* 2010;93:3713–3721.
22. Stewart S, Godden S, Bey R et al. Preventing bacterial contamination and proliferation during the harvest, storage, and feeding of fresh bovine colostrum. *J Dairy Sci* 2005;88:2571–2578.
23. James RE, Polan CE, Zanartu D. Effect of orally administered duodenal fluid on serum gamma globulin levels in neonatal calves. *J Dairy Sci* 1977;60 (Suppl 1):168.
24. James RE, Polan CE. Effect of orally administered duodenal fluid on serum proteins in neonatal calves. *J Dairy Sci* 1978;61:1444–1449.
25. James RE, Polan CE, Cummins KA. Influence of administered indigenous microorganisms on uptake of [Iodine-125] γ-Globulin in vivo by intestinal segments of neonatal calves. *J Dairy Sci* 1981;64:52–61.
26. Elizondo-Salazar JA, Heinrichs AJ. Feeding heat-treated colostrum or unheated colostrum with two different bacterial concentrations to neonatal dairy calves. *J Dairy Sci* 2009;92:4565–4571.

Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site: http://onlinelibrary.wiley.com/doi/10.1111/avj.12683/suppinfo.

Supplementary Table 1. Survey responses of 58 northern Victorian dairy herds on calf and colostrum management practices and the current industry recommendation (where appropriate).

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