A Survey of Bovine Colostrum Composition and Colostrum Management Practices on Pennsylvania Dairy Farms¹

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ABSTRACT

Colostrum composition and management were surveyed via sample and data collection from 55 dairy farms in Pennsylvania. Colostrum samples were analyzed for fat, protein, lactose, total solids, ash, Ig, lactoferrin, water- and fat-soluble vitamins, and minerals. Mean percentages of fat, protein, and lactose in colostrum were 6.7, 14.9, and 2.5, respectively. Concentrations of IgG₁, IgG₂, IgA, IgM, and lactoferrin were 35.0, 6.0, 1.7, 4.3, and 0.8 mg/mL, respectively. Mean concentrations of fat-soluble vitamins, including retinol, tocopherol, and β -carotene, were 4.9, 2.9, and 0.7 μ g/g, respectively. Mean concentrations of water-soluble vitamins were 0.34, 0.90, 4.55, 0.60, 0.15, 0.21, and 0.04 μ g/mL for niacin, thiamine, riboflavin, vitamin B₁₂, pyridoxal, pyridoxamine, and pyridoxine, respectively. Mean concentrations (mg/kg) of selected minerals in colostrum were also determined (Ca 4,716; P 4,452; Mg 733; Na 1,058; K 2,845; Zn 38; Fe 5.3; Cu 0.3; S 2,595; and Mn 0.1). The findings of this study revealed that the mean concentrations of most nutrients in colostrum have increased when compared with values previously reported. Results also showed that management practices have improved over time, particularly with regard to colostrum storage and feeding. Additionally, we observed that herd size influenced colostrum management and quality. It can be inferred, based on these findings, that although improvements have been made with regard to colostrum management and quality, there is still a need to educate producers on issues related to storage and timely feeding of colostrum to increase passive transfer and decrease the rate of calf morbidity and mortality.

Key words: colostrum composition, colostrum management, dairy calf, Pennsylvania

INTRODUCTION

Management and feeding of high-quality colostrum can reduce calf mortality, strengthen immunity, and increase animal life span (Quigley and Drewry, 1998). Delaying the intake of colostrum reduces passive transfer of Ig and postpones provision of essential nutrients that supplement the meager reserves in the bovine neonate.

The composition of colostrum is important in satisfying the nutritional requirements of neonatal dairy calves, particularly for nutrients that only minimally cross the placenta, such as fat-soluble vitamins (Spielman et al., 1946). Calves also require fat and protein for energy and muscle development in the first days of life, as well as growth factors and many other nutrients that are concentrated in the first lacteal secretions of the dam postcalving (Roy, 1990; Quigley and Drewry, 1998). Despite the importance of nutrients in colostrum, published data describing bovine colostrum composition are extremely limited. Foley and Otterby (1978) reviewed the literature on bovine colostrum composition nearly 30 yr ago; however, to our knowledge, no comprehensive research on colostrum composition has been published since then.

Most research investigating colostrum focuses narrowly on IgG and ignores other Ig and nutrients. In addition, limited work has examined the relationship between the nutritive values of colostrum and management practices. Recently, Zanker et al. (2000) showed that calves receiving colostrum 12 to 25 h after birth had lower plasma concentrations of β -carotene, retinol, and α -tocopherol for nearly a month after birth compared with calves that received colostrum within 7 h of birth. Although IgG transfer is the most important factor affecting calf health and survival, it is possible that the exclusive focus on IgG has obscured the value of other components of colostrum. Elucidation of normal levels of these other components and examination of the impact of management practices on them may provide

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additional routes for improving calf health. This information has particular application to the formulation of colostrum supplements and replacers.

It is well established that management practices affect morbidity, mortality, and passive transfer of immunity in dairy calves. According to the 2002 report of the US National Animal Health Monitoring System (NAHMS), 30.5% of producers still provide colostrum by allowing calves to nurse their dams (USDA, 2002). By comparison, this number was 33.7% in the 1991 NAHMS survey. However, this is a significant improvement from a 1973 survey, which showed that 77% of Michigan dairies allowed calves to nurse their dams (Speicher and Hepp, 1973). Farms in Pennsylvania that separate calves and feed colostrum manually, either by bottle or tube, reported an average of 2.7 h until calves were fed first colostrum after birth (Heinrichs et al., 1987). Swedish farmers reported the first colostrum feeding within an average of 3 h after birth (Svensson et al., 2003), whereas only 60% of Alberta farms fed calves within 4 h of birth.

The most recent survey of colostrum management and calf care in Pennsylvania was published 20 yr ago (Heinrichs et al., 1987). Over the last 3 decades, dairy management and nutrition practices, and nutrient analysis techniques have changed considerably. This necessitates the evaluation of bovine colostrum composition and colostrum management practices in light of the many changes in the dairy industry. The first objective of the current study was to record methods used for handling, storing, feeding, and managing colostrum on Pennsylvania farms. The second objective was to analyze the nutrient composition and contents of colostrum in comparison with other research. This analysis of colostrum management and nutrient content will enable the identification of areas in need of improvement to allow for the increased survival of dairy calves.

MATERIALS AND METHODS

Description of Questionnaire and Herds

A questionnaire was developed to obtain information about the management of colostrum, which included milking procedures, storage of colostrum, and treatment protocols. Calf feeding questions included time of feeding after birth, volume fed, and feeding method. The prototype questionnaire was field tested, after which redundancies and unclear questions were modified. The refined 33-item questionnaire was administered by a single interviewer and required about 15 min for completion. All procedures were approved by the Human Subjects Review Committee at The Pennsylvania State University, and all subjects gave informed, written consent.

A representative sample consisting of 55 Holstein dairy herds in 15 Pennsylvania counties were surveyed for colostrum management practices, and colostrum samples were collected from these farms for determination of colostrum composition. The 15 counties selected accounted for nearly 90% of all dairy operations in Pennsylvania because of industry concentration in the 4 regions surveyed (Pennsylvania Agricultural Statistical Report, 2003). Colostrum samples were collected and surveys administered from July 2004 through March 2005.

Determination of Colostrum Composition

Processing of Colostrum for Analysis. Producers were asked to retain a sample of colostrum within 3 d of the on-farm interview. One cow per farm was fully milked out within 4 h of calving, and colostrum was mixed thoroughly, sampled into a container, and then refrigerated. Samples were then transported on ice to the laboratory, where eleven 25-mL aliquots of each sample were taken and stored at -20°C for later analyses.

Ig and Lactoferrin. Immunoglobulins G₁, G₂, M, and A were analyzed by radial immunodiffusion (RID) (Kits E10-116, 117, 118, 121, and 101, Bethyl Laboratories, Montgomery, TX). Colostrum dilutions were made with saline and consisted of 4-fold dilutions for IgA and IgM, a 10-fold dilution for IgG₁, and a 2-fold dilution for IgG₂. All samples and kits were brought to room temperature and samples were thoroughly mixed before use. Because of the viscous nature of colostrum, each assay was controlled with a BSA standard as well as an aliquot of colostrum from the same cow to ensure that kits were within the appropriate range of the standards. A regression coefficient of 95% or higher was used to ensure the accuracy of assays. Lactoferrin was analyzed by ELISA (Kit E10-126, Bethyl Laboratories).

Vitamins. β -Carotene, retinol, and tocopherol were extracted according to methods from *Vitamin Analysis for the Health and Food Sciences* (Eitenmiller and Landen, 1999) and analyzed by HPLC techniques as described by Arnaud et al. (1991). Water-soluble vitamins, including niacin, pyridoxal, pyridoxine, pyridoxamine, folic acid, riboflavin, vitamin B₁₂, and thiamin, were analyzed by the HPLC method described by Albala-Hurtado et al. (1997) at the Proteomics Facility of the Huck Institutes of the Life Sciences at The Pennsylvania State University.

Minerals. One aliquot of colostrum was freeze-dried and analyzed for Ca, P, Na, K, Mg, Mn, Fe, Cu, Zn, and S by Environmental Protection Agency (EPA) method 3051 to microwave digest samples with nitric acid. After digestion, samples were analyzed by EPA method 6010

with inductively coupled plasma spectrometry (US EPA, 1986).

Fat, Lactose, and Protein. Fat was analyzed according to the Babcock procedure as described in *Standard Methods for the Examination of Dairy Products* (Wehr and Frank, 2004), and lactose was analyzed following the method of Feitosa Teles et al. (1978). Crude protein was analyzed by Kjeldahl analysis and corrected by using a factor of 6.38. Total solids and ash were analyzed following AOAC methods (1975).

Statistical Analysis

The GLM procedure of SAS 8.2 (SAS Institute, 2002) was used to analyze differences between nutrients and survey data. Questions, nutrients, and correlations were also analyzed by herd size, with herds categorized as small (≤ 100 cows; $n = 17$), medium (101 to 200 cows; $n = 10$), or large (≥ 201 cows; $n = 28$) based on the number of cows. Each nutrient analysis was correlated with all 33 survey questions by using the GLM procedure; significance was declared at $P < 0.05$ and trends at $P < 0.15$.

RESULTS AND DISCUSSION

Colostrum Composition

The compositional analysis of colostrum content from samples collected from cows in Pennsylvania is presented in Table 1. The findings of our study were compared with the concentrations reported by Foley and Otterby (1978), the last published review of colostrum composition. Components such as lactoferrin and individual IgG subclasses were analyzed in the current study but were not reported by Foley and Otterby (1978) because of the lack of an adequate methodology for analyzing these components at that time. For nutrient composition, 55 samples were analyzed, except for fat, for which 1 sample was not recorded; only 23 mineral samples of manganese were quantified because the other samples were too low to quantify. Fifty-four samples were analyzed for water-soluble vitamins; only 5 samples were quantifiable for vitamin B₁₂ and pyridoxine.

Fat was measured at an average of $6.7 \pm 4.2\%$, which was similar to previous reviews. Parrish et al. (1950), who measured fat by using the same procedure (Babcock) as in the current review, reported a value of $6.7 \pm 2.7\%$. Fat content in colostrum is less likely to be affected by feeding different levels of dietary fat during gestation (Dietz et al., 2003).

Protein ($14.9 \pm 3.3\%$) concentration in colostrum was also similar between reviews, further illustrating the lack of influence of dietary factors. Researchers have

reported that beef heifers restricted in protein intake gained less weight during the last trimester, with no effect on colostrum energy and protein content (Carsens et al., 1987).

Mean lactose content was $2.5 \pm 0.7\%$ and was similar to other reports (Parrish et al., 1950). Lactose concentrations are reduced in colostrum and act inversely of other constituents, such as solids, protein, and ash, which are all found in high concentrations and decrease over time. This coincides with the physiology of the neonate calf, in which lactase is found in low concentrations at birth and increases over time (Zabielski et al., 1999).

The concentration of IgG₁ was 34.9 ± 12.2 mg/mL, which was higher than the report by Foley and Otterby (1978) of 32 mg/mL of total IgG, of which IgG₁ was approximately 85%. In other more recent work, Pritchett et al. (1991) found an average of 48.2 ± 28.9 mg/mL for IgG₁, indicating the need for improving colostrum Ig concentrations. Previous research has indicated that nutrient availability prepartum does not significantly affect the colostrum IgG content. Halliday et al. (1978) reported no differences in colostrum IgG and total protein content when beef cows were fed 12 wk before parturition on diets ranging from 65 to 125% of maintenance for 2 consecutive years.

Other factors do play a role in the Ig content of colostrum. The volume of colostrum produced, parity, dry period length, vaccination, and many other factors have been reviewed and have been reported to affect the IgG content (Weaver et al., 2000). Any of these factors may have played a role in accounting for the low IgG content of some samples in the current survey, although without knowing which factors were different, they could not be accounted for in this survey.

Concentrations of IgA in the current study were much lower than those in previous research. In the current survey, IgA was obtained by RID; however, in other studies microdiffusion discs were used (Masseyeff and Zisswiller, 1969). Because of the low concentrations of IgA and the high solids content of bovine colostrum, the specificity and sensitivity of the RID may have been slightly altered. Most studies have reported values between 3 and 4 mg/mL (Porter, 1972), whereas the current survey reports a value of 1.66 mg/mL.

Concentrations of IgM for the current study (4.32 mg/mL) fall within the range of literature values because of the high variation of IgM concentrations, which ranged anywhere from 3 to 12 mg/mL. Variation in IgM as well as IgA also may be influenced by parity, breed, vaccinations, health status, and other factors, similar to IgG (Porter, 1972). Furthermore, there is currently a need for more reliable and repeatable assays that can take into account the high solids content of colostrum.

Table 1. Compositional analysis of colostrum from samples collected from cows in Pennsylvania

Item	n	Mean	SE	Minimum	Maximum	Foley and Otterby (1978)
Fat, %	54	6.70	4.16	2.0	26.5	6.7
Protein, %	55	14.92	3.32	7.1	22.6	14.0
Lactose, %	55	2.49	0.65	1.2	5.2	2.7
Total solids, %	55	27.64	5.84	18.3	43.3	23.9
Ash, %	55	0.05	0.01	0.02	0.07	—
IgG, mg/mL	—	—	—	—	—	32.0
IgG ₁ , mg/mL	55	34.96	12.23	11.8	74.2	—
IgG ₂ , mg/mL	55	6.00	2.82	2.7	20.6	—
IgA, mg/mL	55	1.66	0.99	0.5	4.4	—
IgM, mg/mL	55	4.32	2.84	1.1	21.0	—
Lactoferrin, mg/mL	55	0.82	0.54	0.1	2.2	—
Retinol, µg/g	55	4.90	1.82	1.4	19.3	2.8
Tocopherol, µg/g	55	2.92	3.65	0.6	10.4	—
β-Carotene, µg/g	55	0.68	0.63	0.1	3.4	—
Vitamin E, µg/g of fat	55	77.17	33.51	24.2	177.9	84.0
Thiamin, µg/mL	54	0.90	0.28	0.3	2.1	0.58
Riboflavin, µg/mL	54	4.55	0.31	2.4	9.2	4.83
Niacin, µg/mL	54	0.34	1.57	0.0	1.6	0.96
Vitamin B ₁₂ , µg/mL	5	0.60	0.35	0.2	1.1	0.05
Folic acid, µg/mL	—	—	—	—	—	0.01
Pyridoxal, µg/mL	54	0.15	0.07	0.1	0.3	—
Pyridoxamine, µg/mL	54	0.21	0.07	0.1	0.5	—
Pyridoxine, µg/mL	5	0.04	0.07	0.0	0.2	—
Pantothenic acid, µg/mL	—	—	—	—	—	1.7
Ca, mg/kg	55	4,716.10	1,898.00	1,775.1	8,593.5	2,599.9
P, mg/kg	55	4,452.10	1,706.29	1,792.4	8,593.5	—
Mg, mg/kg	55	733.24	286.07	230.3	1,399.6	399.9
Na, mg/kg	55	1,058.93	526.02	329.7	2,967.8	699.9
K, mg/kg	55	2,845.89	1,159.89	983.2	5,511.4	1,399.9
Zn, mg/kg	55	38.10	15.90	11.2	83.6	11.6
Fe, mg/kg	55	5.33	3.09	1.7	17.5	1.9
Cu, mg/kg	55	0.34	0.14	0.13	0.64	0.6
S, mg/kg	55	2,595.67	904.97	889.4	4,143.7	—
Mn, ¹ mg/kg	23	0.10	0.11	0.0	0.36	0.2

¹Part of the samples were quantified as <0.05 and therefore not included in averages.

Lactoferrin is a glycoprotein that binds iron and has been shown to reduce morbidity and improve growth in neonatal dairy calves (Robblee et al., 2003). As analyzed by ELISA in the current study, lactoferrin averaged 0.82 ± 0.54 mg/mL. Bovine colostrum contains lower lactoferrin concentrations than other species; Yoshida et al. (2000) reported an average of 0.34 ± 0.23 mg/mL for 6 cows by using chromatography. In contrast, Tsuji et al. (1990) reported an average of 1.96 ± 0.27 mg/mL for 45 Holstein cows by RIA. Differences may exist because of laboratory techniques; however, bovine colostrum does contain lower lactoferrin concentrations than other species (Masson and Heremans, 1971).

Fat-soluble vitamins are an important component in colostrum. Although tocopherols pass through placental membranes and are stored by the fetus, neonates are still born with low tocopherol levels and rely on colostrum for this nutrient (Zanker et al., 2000). The results for fat-soluble vitamin concentrations in colostrum were similar between reports; however, retinol

concentrations were numerically higher in the current survey compared with that of Foley and Otterby (1978). This may be due to the high variation in concentrations of fat-soluble vitamins among individuals as well as the dependence on maternal reserve status, diet, and season. Recently, more emphasis has been placed on dry cow nutrition, which may result in higher fat-soluble vitamin concentrations in colostrum because increased dietary levels also increase colostrum levels (Weiss et al., 1990). Stewart and McCallum (1938) reported variations in retinol ranging from 35 to 1,181 IU/100 mL of colostrum among individual cows on the same management system; this result highlights intersample variation. Many other studies have not used fat concentrations when analyzing fat-soluble vitamin concentrations, which can affect the results because of their high correlation. Weiss et al. (1990) found a significant correlation between fat in colostrum and fat-soluble vitamin concentrations.

Water-soluble vitamins have not been extensively analyzed in colostrum. Before HPLC, researchers at-

tempting these analyses used methods such as rat growth and a variety of microbiological, chemical, and fluorometric assays, which resulted in variability among assays and technicians. For example, Roderuck et al. (1945) reported a 20% increase in riboflavin content with microbiological assays compared with fluorometric analysis because of the difficulty of replicating microbiological methods. The means of water-soluble vitamins analyzed by HPLC for the current study were 0.34, 0.90, 4.55, 0.60, 0.15, 0.21, and 0.04 $\mu\text{g/mL}$ for niacin, thiamin, riboflavin, vitamin B₁₂, pyridoxal, pyridoxamine, and pyridoxine, respectively. However vitamin B₁₂ and pyridoxine were quantifiable in only 5 farm samples. The review by Foley and Otterby of data before 1978 included pantothenic acid and folate, which were not analyzed in the current study. Data from the past review were much lower for concentrations of thiamin and vitamin B₁₂, higher for niacin, and similar for riboflavin. Some past research used values of thiamin, niacin, and riboflavin from pooled colostrum of Holsteins and Jerseys, with methods ranging from microbiological and fluorometric to enzymatic methods, depending on the study.

Analyses of colostrum samples in the current survey resulted in values that were higher than those reported by Foley and Otterby (1978) for all minerals except copper and manganese. Kume and Tanabe (1993) indicated that minerals were highest in colostrum to provide calves with minerals after birth. Although most minerals are found in sufficient amounts in colostrum, concentrations depend on diet and parity of the dam, and this can result in mineral deficiencies in calves if supplementation is not provided (Kume and Tanabe, 1993).

Survey Results

Management of dry cows (Table 2) included vaccinations, housing, and supplemental vitamins, among other items. Straw was the predominant bedding material used in maternity pens (55%), similar to previous survey results in which 57.2% of farms also used straw (Heinrichs et al., 1987). This was likely due to the cost and availability of straw in the Northeast at the time the surveys were conducted. All farms surveyed vaccinated dry cows; of these farms, 29% used vaccines for *J-5 Escherichia coli* bacteria and bovine viral diarrhea. Properly timed vaccinations increase the transfer of Ig specific for diseases and enhance the protection of calves through passive transfer, thereby improving the quality of the colostrum.

The amount, timing, and delivery of colostrum to heifer calves were surveyed (Table 3). Calves were fed by bottle on 87% of farms, and only 1 farm allowed

calves to nurse the dam. This is an improvement from a previous Pennsylvania survey, which reported 22% of calves nursing off the dam unassisted (Heinrichs et al., 1987), and from the 2002 NAHMS study, in which 30.5% calves nursed.

Calves need to be fed colostrum in a timely manner, and most farms provide calves with colostrum within 4 h of birth. In Pennsylvania, calves received colostrum an average of 2.7 h after birth, and in Alberta 60% of calves received colostrum within 4 h (Heinrichs et al., 1987). In the current study, 43.6% of farms fed calves colostrum within 2 h after birth, and 51% fed colostrum between 2 and 6 h after birth.

In the current survey, calves were fed an average of 2 to 4 L of first-milking colostrum for the first feeding on 57% of farms; however, 37% fed 1.89 L or less for the first feeding. Previous survey results are similar, with an average of 2.8 kg fed for the first feeding (Heinrichs et al., 1987). Additionally, only 74% of farms in the current survey fed a second feeding of first-milking colostrum. The amount that calves were fed for the first feeding and whether a second feeding was fed were positively related ($P < 0.05$), and 9% of farms that fed 1.89 L or less for the first feeding did not feed a second feeding of first-milking colostrum, which could dramatically increase the chance for failure of passive transfer and subsequently raise the risk of mortality (Weaver et al., 2000).

The handling, storing, and milking of colostrum were also reported (Table 4). Use of frozen colostrum increased from 22% in a survey conducted by Heinrichs et al. (1987) to 38% currently, indicating increased awareness of the importance of timely colostrum feeding.

Correlations Between Nutrients and Survey Questions

Nutrient composition was compared with survey results; however, there were few statistically significant correlations. Farms with herd average SCC <200,000 in the month before samples were collected had colostrum with significantly greater tocopherol, vitamin A, potassium, IgG₂, and TS ($6.38 \pm 0.82 \mu\text{g/g}$, $3.61 \pm 0.42 \mu\text{g/g}$, $1,722.56 \pm 183.55 \text{ mg/kg}$, $7.27 \pm 0.61 \text{ mg/mL}$, and $30.29 \pm 1.25\%$, respectively) than farms with SCC >200,000 ($4.22 \pm 0.61 \mu\text{g/g}$, $2.63 \pm 0.31 \mu\text{g/g}$, $5,787.86 \pm 203.38 \text{ mg/kg}$, $5.15 \pm 0.46 \text{ mg/mL}$, and $25.75 \pm 0.95\%$, respectively). The colostrum of cows without mastitis has been reported to contain numerically greater concentrations of vitamin A and β -carotene than the colostrum of mastitic cows (Johnston and Chew, 1984). This indicates that cows housed at dairies with lower SCC counts may produce colostrum that is higher in nutrient

Table 2. Survey responses regarding management of dry cows and heifers before calving by herd size (small, ≤ 100 cows; medium, 101 to 200 cows; large, ≥ 200 cows)

Survey question and answer categories, % of farms	Herd size			
	Small	Medium	Large	All herds
What was the somatic cell count from the previous month?				
<200,000	50	50	25	36
>200,000	50	50	75	64
Do you add a vitamin-mineral premix to the dry cow diet?				
No	24	0	4	9
Yes	76	100	96	91
What vaccinations are given to dry cows?				
J-5	18	0	18	16
ScourGuard ¹	24	30	14	22
J-5 and bovine viral diarrhea	24	40	25	29
J-5, bovine viral diarrhea, ScourGuard	12	0	14	12
Other	22	30	29	21
Are cows given any vitamin injections during the dry period?				
No	65	50	50	59
Vitamin E and selenium	29	20	0	28
Other	6	30	50	13
What type of bedding are dry cows housed on in the maternity barn at calving?				
Straw	59	60	50	55
Hay	18	0	0	5
Shavings and straw	6	10	11	7
Other	17	30	39	33
How many cows are grouped in maternity pens?				
Individually	24	20	25	24
Groups of 2–4	24	20	7	14
Groups of 5 or more	52	60	68	62
Are prefresh heifers housed in the same maternity pens near or with older cows?				
Yes	100	90	93	96
No	0	10	7	4
How long are heifers housed with older cows before calving?				
>2 mo	25	40	14	23
1–2 mo	38	10	30	28
<1 mo	37	40	52	45
Not housed together	0	10	4	4
In the last year, have you tested for . . . ?				
Johne's disease	12	20	14	15
Johne's disease and bovine viral diarrhea	35	50	46	45
Johne's disease, bovine viral diarrhea, and leukosis	12	10	18	15
None	35	0	0	11
Other	6	20	21	14

¹ScourGuard, Pfizer Inc., New York, NY.

quality. In contrast, niacin was found in significantly greater concentrations ($P < 0.02$) for farms with SCC $> 200,000$ (0.45 ± 0.07 $\mu\text{g/mL}$) compared with farms with SCC $< 200,000$ (0.23 ± 0.07 $\mu\text{g/mL}$).

Means for lactose were greater for farms that did not give vitamin injections than for farms that used vitamin injections during the dry period ($3.29 \pm 0.28\%$ and $2.41 \pm 0.09\%$, respectively; $P < 0.004$). The reason for this correlation is unknown.

Correlations by Farm Size

Farm size plays a role in the management of farms and may reflect on colostrum quality. The current survey included 17 farms with ≤ 100 cows, 10 farms with 101 to 200 cows, and 28 farms with ≥ 201 cows. Fewer small farms fed a vitamin-mineral premix to dry cows

compared with farms with medium and large herds ($P < 0.04$). A colostrometer was used on 43% of large farms compared with 10% of medium farms and 12% of small farms. Eleven percent of large farms reported using a pasteurizer, whereas no farms with ≤ 200 cows used a pasteurizer ($P < 0.09$). This may be due to the availability of resources and the use of larger equipment on larger farms. Farms that used a pasteurizer also used a colostrometer ($P < 0.01$) and did not feed colostrum to calves from their respective dams ($P < 0.02$).

Larger farms also stored more colostrum. Of small farms, 59% reported not storing any colostrum compared with 21% of large farms. This is most likely because smaller farms had fewer calves and fed colostrum to calves directly from their respective dams. Eighty-nine percent of small and medium farms reported feeding colostrum to calves from their respective dams com-

Table 3. Survey responses regarding feeding of colostrum to newborn heifer calves by herd size (small, ≤100 cows; medium, 101 to 200 cows; large, ≥200 cows)

Survey question and answer categories, % of farms	Herd size			
	Small	Medium	Large	All herds
How much colostrum do heifer calves receive for the first feeding?				
1.89 L or less	29	56	36	37
1.89 to 3.79 L	59	44	60	57
3.79 L or more	12	0	4	6
Do calves receive 2 feedings of colostrum?				
Yes	82	50	71	74
No second feeding	18	50	29	26
How is colostrum fed to calves?				
Allowed to nurse off the dam	0	0	4	2
Hand-fed from bucket or bottle	100	80	82	87
Hand-fed using esophageal feeder	0	20	14	11
When are heifer calves fed colostrum?				
Within the first 2 h	41	40	46	44
Within 2 to 6 h	47	60	50	51
After 6 h	12	0	4	5
When are heifer calves fed the second feeding of colostrum?				
6 to 8 h later	24	0	21	20
8 to 12 h later	41	50	50	53
12 to 24 h later	6	0	0	2
Not fed a second feeding	29	50	29	25

Table 4. Survey responses regarding management and storage of colostrum by herd size (small, ≤100 cows; medium, 101 to 200 cows; large, ≥200 cows)

Survey question and answer categories, % of farms	Herd size			
	Small	Medium	Large	All herds
On average how long after calving is a cow milked for first colostrum?				
Immediately, <1 h	12	10	0	6
1 to 2 h	29	10	11	16
2 to 6 h	35	60	68	56
>6 h	24	20	21	22
If colostrum is stored, what kind of container is it stored in?				
Open-topped container	6	0	11	7
Closed container	35	50	68	55
Not stored	59	50	21	38
How is colostrum stored after milking?				
Frozen	35	40	39	38
Refrigerator	6	10	36	22
Stored without refrigeration	0	0	4	2
Not stored	59	50	21	38
Are calves fed colostrum from their own dam?				
Yes	88	80	43	65
No	12	20	57	35
Is colostrum used from first-calf heifers?				
Yes	88	70	75	78
No—Is there a source of stored colostrum (fresh or frozen)?				
Yes	0	10	11	7
No	12	20	14	15
Is first-milking colostrum pooled?				
Yes	18	0	21	16
No	82	100	79	84
Is a colostrum supplement used in addition to colostrum?				
Yes	6	20	25	18
No	94	80	75	82
Do you use a colostrometer?				
Yes	12	10	43	27
No	88	90	57	73
Is a pasteurizer used on the farm?				
Yes	0	0	11	5
No	100	100	89	95

pared with only 43% of large farms. This result is supported by findings of the NAHMS (2002) survey, which showed that 65.4% of farms with less than 100 cows did not store colostrum compared with 44.6% of farms with 100 to 499 cows. This may lead to higher calf mortality on small farms, as found by the NAHMS (2002) survey, which reported that calf mortality decreased as herd size increased.

Large farms tended to milk cows later after calving than did medium and small farms ($P < 0.12$). No large farms reported milking cows within 1 to 2 h after calving, compared with 10 to 12% of farms with ≤ 200 cows. Sixty-eight percent of cows on large farms were milked between 2 to 6 h after calving compared with 60% of medium farms and 35% of small farms. Furthermore, 67% of large farms reported that the interval between calving and first milking was similar, whether cows calved during the day or at night. In contrast, 35% of small farms and 40% of medium farms reported that this interval was longer if cows calved at night. This is an example of the difference in resources on small farms, which, although efficient during the day, usually have less labor at night. Therefore, cows must wait to be milked until the day crew begins work.

Analyzing farms by different size categories showed some differences; however, farms with ≤ 100 cows and with 101 to 200 cows were more similar than farms with ≥ 201 cows. In summary, we could generalize that smaller farms with fewer than 100 or 200 cows were managed differently from their larger counterparts. Differences in resources, including the availability of workers, finances, and feed, resulted in significant differences in management and colostrum composition.

This farm survey covered the management of colostrum and aspects of dry cow management. A better understanding of how management practices influence colostrum quality can help managers and consultants focus on areas within colostrum management and feeding that need improvement. A previous survey reported improvements in colostrum management and feeding when producers were provided with information regarding calf health (Heinrichs and Kiernan, 1994). After receiving feedback and management recommendations, producers increased the colostrum feeding volume from 2.7 to 3.5 kg and decreased the time of feeding after birth from 2.6 to 2.4 h.

CONCLUSIONS

The current survey revealed certain improvements in the management and feeding of colostrum. The number of farms currently storing frozen colostrum has increased compared with previous surveys. More farms are separating calves from their dams and manually

feeding colostrum, which enhances passive transfer. Several nutrients in colostrum have also increased in concentration, indicating that dry cows may be receiving diets that more adequately meet their nutrient requirements.

Differences were found in management and nutrient concentrations between small and large farms. Larger farms reported longer times of milking colostrum after calving, higher SCC, and a lower nutrient content of colostrum compared with small farms. However, more large farms stored colostrum, fed a mineral-vitamin supplement, and used a colostrometer compared with small farms. Improvements in colostrum management and feeding can be better focused by considering farm size.

Nevertheless, there is still room for improvement, as indicated by the steadily increasing calf mortality rate reported in the NAHMS (2002) survey. Education in colostrum management and feeding needs to be emphasized and must be continued to keep improving the care of dairy calves.

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