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Composition and Hygiene of Colostrum on Modern Pennsylvania Dairy Farms

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Topics include:

Nutrient composition
Immunoglobulin composition
Bacterial contamination
Colostrum from heifers compared to cows
Effects of colostrum volume

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INTRODUCTION

Calf health, growth, and productivity rely heavily on nutrition and management practices on the farm. Every heifer calf born on a dairy farm represents an opportunity to maintain or increase herd size, to improve the herd genetically, and to improve economic returns to the farm. Colostrum is the all important first feed for the dairy calf that allows the calf to be healthy and begin to grow. It provides much needed nutrients, particularly those that cross the placenta in limited quantities, and, most importantly, maternal antibodies that protect calves from disease.

This report is a summary of Penn State research into the composition of modern-day colostrum. With the exception of immunoglobulin concentrations, it has been many years since colostrum composition has been studied in detail. The most recent comprehensive study of bovine colostrum was a summary of published research by Foley and Otterby in 1978. Over time changes in genetics, management, and nutrition may have impacted what is currently found in Holstein colostrum, so we set out to see what is in colostrum today. We visited 55 farms in four major dairy areas in Pennsylvania and collected colostrum samples from Holstein cows.

Colostrum composition from samples collected in this study is presented in Table 1 and compared to the results reported by Foley and Otterby. There are a few differences in the nutrients analyzed between the two studies, primarily due to differences in analytical procedures available. Nutrient composition was determined in 55 samples, except for manganese, which was only quantifiable in 23 samples, and vitamin B12 and pyridoxine, which were only quantifiable in 5 samples.

MAJOR NUTRIENTS

The first components measured were fat, protein, lactose and total solids. Our analysis showed that these major nutrients had not changed much compared to the values reported 40 years ago (Table 1). The lack of a change over time was not unexpected because the concentration of these major nutrients in colostrum does not seem to be greatly affected by changes in the diet of cows before calving except in the case of extreme nutrient restriction.

While the average looked good, the range of samples was very wide. Many samples contained adequate to exceptional levels of nutrients, but the minimum values show that some of the samples contained very few nutrients. The lowest samples analyzed were so poor that calves receiving such colostrum as a first feeding would not have obtained enough nutrients to get them off to a good start. Although we only collected one sample from each herd in this study, previous research shows that colostrum composition can vary considerably between individual cows, even in the same herd.

Although there are some cows that produce so much first milking colostrum that nutrient concentrations are diluted, milking the cow as soon as possible after calving is very important to obtain colostrum with the highest nutrient levels possible. Collect colostrum within two hours of calving for the best results.

Table 1. Composition of 55 colostrum samples from Pennsylvania farms

Item	n	Average	Minimum	Maximum	1978 Review
Fat, %	54	6.70	2.0	26.5	6.7
Protein, %	55	14.92	7.1	22.6	14.0
Lactose, %	55	2.49	1.2	5.2	2.7
Total solids, %	55	27.64	18.3	43.3	23.9
Ash, %	55	0.05	0.02	0.07	1.11
Total IgG[1], mg/mL		46.94	16.1	120.2	32.0
IgG_1, mg/mL	55	34.96	11.8	74.2	-
IgG_2, mg/mL	55	6.00	2.7	20.6	-
IgA, mg/mL	55	1.66	0.5	4.4	-
IgM, mg/mL	55	4.32	1.1	21.0	-
Lactoferrin, mg/mL	55	0.82	0.1	2.2	-
					-
Retinol, µg/g	55	4.90	1.4	19.3	2.8
Tocopherol, µg/g	55	2.92	0.6	10.4	-
β-Carotene, µg/g	55	0.68	0.1	3.4	-
Vitamin E, µg/g fat	55	77.17	24.2	177.9	84.0
Thiamin, µg/mL	54	0.90	0.3	2.1	0.58
Riboflavin, µg/mL	54	4.55	2.4	9.2	4.83
Niacin, µg/mL	54	0.34	0.0	1.6	0.96
Vitamin B_{12}, µg/mL	5	0.60	0.2	1.1	0.05
Folic acid, µg/mL	-	-	-	-	0.01
Pyridoxal, µg/mL	54	0.15	0.1	0.3	-
Pyridoxamine, µg/mL	54	0.21	0.1	0.5	-
Pyridoxine, µg/mL	5	0.04	0.0	0.2	-
Pantothenic acid, µg/mL	-	-	-	-	1.7
Calcium, mg/kg	55	4,716.10	1,775.1	8,593.5	2,599.9
Phosphorus, mg/kg	55	4,452.10	1,792.4	8,593.5	-
Magnesium, mg/kg	55	733.24	230.3	1,399.6	399.9
Sodium, mg/kg	55	1,058.93	329.7	2,967.8	699.9
Potassium, mg/kg	55	2,845.89	983.2	5,511.4	1,399.9
Zinc, mg/kg	55	38.10	11.2	83.6	11.6
Iron, mg/kg	55	5.33	1.7	17.5	1.9
Copper, mg/kg	55	0.34	0.13	0.64	0.6
Sulfur, mg/kg	55	2,595.67	889.4	4,143.7	-
Manganese[2], mg/kg	23	0.10	0.0	0.36	0.2

Sources: Current survey, Kehoe et al., 2007; historical data, Foley and Otterby, 1978.

[1]Total IgG in the current study was calculated by adding the concentration of each type.

[2]Samples that were quantified <0.05 mg/kg were not included in average.

MINERALS AND VITAMINS

Mineral concentrations in the current survey were noticeably higher than those summarized by Foley and Otterby except for copper and manganese. Mineral concentrations in colostrum depend on the diet of the dam, and the increase in minerals over time most likely reflects more attention to feeding minerals to dry cows and springing heifers than in years past.

Fat-soluble vitamin concentrations in colostrum were similar between this study and the Foley and Otterby report, but retinol was higher in the current survey. Similar concentrations of fat-soluble vitamins over time may be due to high variation between individuals and the effect of maternal reserves, diet, and season. Recently more emphasis has been placed on dry cow nutrition, which may result in higher fat-soluble vitamin concentrations in colostrum since providing more vitamins in the diet increases colostrum levels. Fat-soluble vitamin concentrations are also related to fat levels in colostrum.

Water soluble vitamins have not been extensively analyzed in colostrum due to the difficulty and variability of lab methods that were used before high performance liquid chromatography (HPLC) became available. Water-soluble vitamin concentrations were much higher for thiamin and vitamin B12, lower for niacin, and similar for riboflavin when compared to the Foley and Otterby review. Vitamin B12 and pyridoxine were only quantifiable in 5 samples. These data should be considered preliminary and comparisons to older data should be made with caution because of much of the older research utilized analytical techniques with known limitations.

Overall, minerals and vitamins in modern colostrum appear to be quite adequate due to improvements in feeding these nutrients to dry cows and springing heifers. As a result, supplemental mineral and vitamin injections for newborn calves are no longer necessary in many cases.

IMMUNOGLOBULINS

The concentration of immunoglobulins has received much attention and more study than other components. Similar to the results of most other reports, in this survey values ranged widely (Table 1). Total immunoglobulin concentration of the samples was only 47 mg/mL on average. Generally, 50 mg/mL is considered the cutoff point for good versus marginal colostrum. So on average, our samples contained marginal amounts of immunoglobulin. While some samples were very high and more than adequate, there were as many that were too low, and some, as noted by the minimum numbers, were extremely low. In fact, these lowest samples could not likely be considered to be true colostrum. Calves fed 4 quarts of this lowest quality colostrum would not be able to attain adequate immune protection.

Concentration of IgG1 was slightly higher than reported by Foley and Otterby, while IgA was much lower and IgM was within the range of values reported in the literature. Variation in IgA and IgM can be influenced by parity, breed, vaccination, health status, and other factors similar to IgG. Furthermore, there is currently a need for more reliable and repeatable assays for IgA and IgM that can take into account the high solids content of colostrum.

LACTOFERRIN

Lactoferrin is a glycoprotein that binds iron and has been shown to reduce morbidity and improve growth in neonatal dairy calves. In the current study, lactoferrin was measured using an ELISA test. Levels were within the range of previously reported values. Differences may exist due to laboratory techniques; however, bovine colostrum does contain lower lactoferrin concentrations than other species.

BACTERIAL CONTAMINATION

Standards for bacteria in colostrum are not well established. Past research has shown that *E. coli* introduced into the gut before colostrum feeding can reduce the amount of IgG absorbed by calves. But, in a Penn State study calves fed colostrum that contained a high bacterial load (>400,000 cfu/mL standard plate count and >1,000 cfu/mL coliform count) absorbed similar amounts of IgG as calves fed colostrum with a low bacterial load (approximately 9,000 cfu/mL standard plate count and 100 cfu/mL coliform count). In the current survey the average standard plate count was nearly 1 million cfu/mL, and the average coliform count was over 300,000 cfu/mL. All types of bacteria measured varied widely (Table 2).

Table 2. Comparison of bacteria counts in 55 colostrum samples from Pennsylvania farms to goals[1] for bacteria counts in milk fed to calves (n/a indicates bacteria that were not measured in this study)

Item	Goal	Bacteria in Colostrum Surveyed[2], cfu/mL			
	cfu/mL	Average	Median	Minimum	Maximum
Standard plate count	< 20,000	997,539	15,300	140	9,070,000
Coliforms	< 100	323,372	600	0	3,950,000
Staphylococcus aureus	0	306	0	0	12,000
Streptococcus agalactiae[3]	0				
Salmonella[4]	0				
Mycoplasma	0	n/a	n/a	n/a	n/a
Environmental Streptococci	< 5,000	256,722	2,140	0	5,600,000
Environmental Staphylococci	< 5,000	164,963	2,260	0	3,980,000
Non-coliforms	< 5,000	111,544	360	0	3,000,000

[1]Very little research has been done on the exact number of bacteria that is "safe" for calves. The number depends on each calf's immune system and the level of stress from poor nutrition or a wet or dirty environment. Higher levels of bacteria present a greater risk to calf health.
[2]Source: Houser et al., 2008.
[3]*Streptococcus agalactiae* was detected in one sample at 1,000 cfu/mL.
[4]Out of 55 samples, 8 (15%) tested positive for *Salmonella* species.

Goals that have been proposed for colostrum standard plate count range from the 100,000 cfu/mL limit set by the U.S. Pasteurized Milk Ordinance for raw milk being shipped from a farm to 5,000 cfu/mL, which is considered a standard for high quality raw milk. Targets of <10,000 and <20,000 cfu/mL are used for waste milk, although <20,000 cfu/mL seems to be more commonly accepted. The 5,000 cfu/mL standard may be more stringent than necessary for calf milk, and only 35 percent of the samples in this survey had standard plate counts less than 5,000 cfu/mL. Forty percent of samples contained <10,000 cfu/mL, and 55 percent contained <20,000

cfu/mL. Ten percent of the samples in this study were very clean colostrum with standard plate counts <1,000 cfu/mL.

Coliforms are known calf pathogens and need to be kept out of colostrum as much as possible. In this study, 31 percent of samples contained <100 cfu/mL of coliform bacteria and 16 percent had no detectable coliforms.

For consistency with goals for other milk fed to calves, goals presented in Table 2 for colostrum are the same as those recommended for waste milk fed to calves. When establishing targets for an individual farm, consider setting a goal to reduce bacteria compared to current performance.

This survey suggests that some farms have room for improvement in the collection of colostrum. Whether it means more attention to cleaning the udder and teats prior to milking, removing long hair by singeing or clipping the udder, regular cleaning and sanitizing of colostrum milkers and collection buckets, handling both cows and colostrum with clean hands, or storing colostrum in ways that limit bacterial growth, better colostrum collection practices can help reduce the number of bacteria in colostrum and limit the number of potentially harmful bacteria fed to newborn calves.

COLOSTRUM FROM HEIFERS VERSUS COWS

In another Penn State study, we wanted to see if the traditional understanding that heifers have poorer colostrum than older cows was still true. For this study we used three larger farms and analyzed colostrum from every animal that calved during a four-month period. Analysis of the colostrum showed that cows entering their first or second lactation had similar colostrum IgG levels, and these were lower than cows entering third or fourth and greater lactation (Table 3). However, for all lactation groups the average IgG concentration was well above the 50 mg/mL that is often used to separate high quality colostrum from lower quality colostrum. The farms in this study collected colostrum within 2 to 6 hours of calving, which probably contributed to higher than expected IgG concentrations.

This study suggests that heifers can produce high quality colostrum, and there is no need to arbitrarily discard heifer-produced colostrum. This is most likely a result of modern heifer management that includes greater attention to feeding and vaccination programs. Heifer colostrum should be treated like cow colostrum and fed when it meets your quality criteria, which may increase the colostrum supply. While older cows will often have more diversity of antibodies in their colostrum because they have been exposed to more pathogens, heifers can produce quality colostrum.

Table 3. IgG concentration and colostrum volume by lactation

	Lactation				
Item	1	2	3	4+	SEM
Number of cows	172	130	94	93	
IgG, mg/mL	83.5[b]	92.9[b]	107.4[a]	113.3[a]	3.8
Volume, L	6.2	6.1	6.8	6.5	0.5

[a,b]Means in the same row with different superscripts differ ($P < 0.05$)

Source: Kehoe et al., 2011 (in press)

EFFECTS OF COLOSTRUM VOLUME

Past studies have shown that as first milking colostrum volume increases, colostrum quality decreases on average. A common thumb rule is that if a cow gives more than 18 pounds of first colostrum, there is a good probability that the quality will be marginal or low. In the study described above, IgG did drop as the volume of first-milking colostrum increased. But, there was a lot of variation in IgG concentration between cows at any given volume of colostrum, which suggests that there were other factors affecting IgG.

Cows with higher genetic potential for milk production secrete more milk and likely increase secretion faster once calving has occurred. Colostrum from cows that leak milk or are milked before calving will likely have reduced quality. In addition, delayed first milking causes lower IgG levels in colostrum. The drop in IgG as the time between calving and when colostrum is harvested increases may be due to dilution of IgG as the amount of milk secreted increases, re-absorption of immunoglobulins by the cow, or a combination of these factors. Recent research suggests that using the amount of colostrum produced at the first milking as the sole criterion for discarding colostrum may limit the supply of colostrum unnecessarily.

TESTING COLOSTRUM

These studies shed light on composition of colostrum based on a representative sample of Pennsylvania farms. There are several useful tests you can use to find out more about the colostrum you are feeding.

Colostrum IgG can be measured very accurately in the laboratory, but these tests would not provide results quickly enough for on-farm use. A colostrometer, Brix refractometer, or cow-side kit can be used to estimate colostrum IgG content with enough accuracy to separate good quality colostrum (containing >50 mg/mL of IgG) from poor quality (containing <50 mg/mL of IgG).

Colostrum nutrient composition (fat, protein, and total solids) may be available from milk testing labs. Because the results are not available immediately, nutrient analysis will not be helpful in screening colostrum to determine whether it is suitable for feeding to calves.

Bacteria levels in colostrum can be tested in a lab that offers bacterial culture. Again, these results will not be available quickly enough to use in screening colostrum, but they may be useful in troubleshooting colostrum management. Testing standard plate count will provide an estimate of the total amount of bacteria in colostrum. Coliforms may be tested to indicate contamination of colostrum from manure and environmental sources. Other bacteria counts common in milk quality panels can be tested, but do not provide a lot of useful information since many of these are not calf pathogens. Tests for *Salmonella* or *Mycoplasma* may be advised if you have reason to suspect these pathogens are causing problems, but these tests can be more expensive and are not needed for routine monitoring of the colostrum supply.

Although high quality colostrum is typically very thick and creamy, appearance alone does not reliably predict nutritional value, IgG content, or bacteria populations. The one exception is that bloody or mastitic colostrum should be discarded because it has a greater risk of containing endotoxins and very high bacteria counts.

CONCLUSIONS

Many aspects of colostrum management are not new and have not changed over time, however we continually see mortality and morbidity rates at the same levels that were found 15 to 20 years ago. One of the reasons that we are not seeing improvements in calf health in the first few months of life is that colostrum quality and colostrum management practices are not improving as they should. In many cases, small changes in management of the newborn calf and the just-fresh cow can help to reduce illness and death rates.

REFERENCES

Bielmann, V., J. Gillan, N. R. Perkins, A. L. Skidmore, S. Godden, and K. E. Leslie. 2010. An evaluation of Brix refractometry instruments for measurement of colostrum quality in dairy cattle. J. Dairy Sci. 93:3173-3721.

Elizondo-Salazar, J. A., and A. J. Heinrichs. 2009. Feeding heat-treated colostrum or unheated colostrum with two different bacterial concentrations to neonatal dairy calves. J. Dairy Sci. 92 :4565-4571.

Foley, J. A., and D. E. Otterby. 1978. Availability, storage, treatment, composition, and feeding value of surplus colostrum: A review. J. Dairy Sci. 61:1033-1060.

Houser, B. A., S. C. Donaldson, S. I. Kehoe, A. J. Heinrichs, and B. M. Jayarao. 2008. A survey of bacteriological quality and the occurrence of Salmonella in raw bovine colostrum. Foodborne Path. Dis. 5:853-858.

Kehoe, S. I., A. J. Heinrichs, M. L. Moody, C. M. Jones, and M. R. Long. 2011. Comparison of immunoglobulin G concentrations in primiparous and multiparous bovine colostrum. Prof. Anim. Sci. *In press*.

Kehoe, S. I., B. M. Jayarao, and A. J. Heinrichs. 2007. A survey of bovine colostrum composition and colostrum management practices on Pennsylvania dairy farms. J. Dairy Sci. 90:4108-4116.

Additional resources related to colostrum and other calf topics can be found at http://www.das.psu.edu/research-extension/dairy/nutrition/calves.

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