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Calf Note 204 – Colostrum quality and passive immunity in calves in the U.S.

Introduction

The U.S. Department of Agriculture National Animal Health Monitoring System (NAHMS) conducts annual surveys of animal agriculture in the U.S. From time to time, they conduct surveys of calf and heifer management practices. It's a fantastic opportunity to understand the "state of the industry" in the U.S. and, using data from previous studies, determine the rate of change in biologically and economically important

In 2018, a series of manuscripts was published in the Journal of Dairy Science that provided results of the most recent NAHMS study on preweaning calf management. These papers report results from the investigation and provide important insights into how we're doing as an industry in the U.S. This Calf Note will review the factors regarding colostrum quality and passive immunity on dairy farms in the U.S

The Research

During 2014, the USDA surveyed 104 different dairy farms in 13 states. Farms were divided into West (California, Colorado, and Washington) and East (Iowa, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, Vermont, Virginia, and Wisconsin). The survey lasted over 1.5 years and followed calves from birth to weaning. Data regarding colostrum and serum IgG were collected on 1,972 Holstein heifer calves. Note that calves needed to be alive at 24 hours of age to be included in the study; therefore, calves that were stillborn or those that died prior to blood sampling for serum IgG concentration were not included. Only heifer calves were included in the research, also. The researchers monitored colostrum quality and serum IgG (i.e., passive transfer of immunity) as well as many different management, environmental and feeding practices. Then, they evaluated the data statistically to determine which factors affected important outcomes, including factors affecting colostrum quality and the level of serum IgG after 24 hours of age. In other aspects of the NAHMS study, both Jersey and Holstein calves were included. However, for the colstrum aspects, only Holsteins were used. More information on the methods used to collect information from the dairies is available at Shivley et al. (2018).

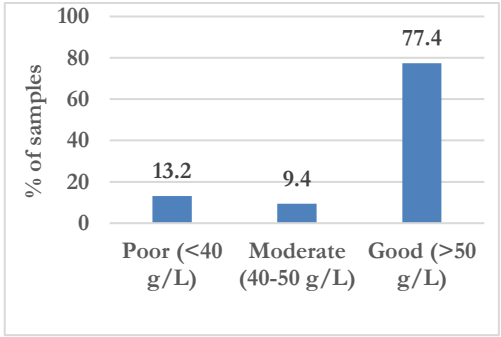

Figure 1. Percent of samples classified as poor, moderate or good quality. Source: Shivley et al., 2018.

Colostrum Quality

Let's take a look at the overall quality of the colostrum reported in the study. The mean colostrum IgG concentration was 74.4 g/L (SE = 0.72), and 77.4% of samples had IgG >50 g/L (Figure 1). The large number of observations (n = 1,972) gives good confidence in these values. The average and variation is greater than the average (68.8 g/L, SE = 1.1) and varation reported by Morrill et al. (2012) who conducted a nationwide evaluation of

colostrum quality in 2012. These researchers measured colostrum IgG in 827 samples collected from 67 farms in 12 states; the USDA study collected samples from 104 farms in 13 states (not all the same states). Morrill et al., reported that 71% of their colostrum samples had IgG concentration ≥50 g/L; this is similar to the proportion from the USDA study (77%).

More recent data from Pennsylvania (Kehoe et al., 2011) also suggest that colostral quality has improved (average = 96.1 g of IgG/L) on well managed farms and a greater proportion (90%) of evaluated colostrum samples exceededing the target of 50 g of IgG/L. All of these large studies are somewhat different from other smaller studies in the literature that often reported far lower colostral IgG concentrations, often with data from one farm (e.g., Abel et al., 1993) or region of the country (Kehoe et al., 2007) (Note: more information on this trial is available in Calf Note #133). Also, Gulliksen et al. (2008) reported that average colostrum IgG concentration in 1,250 Norwegian dairy cows (most cows were Norwegian Red or Norwegian Red cross cattle) was 45 g of IgG/L of colostrum, significantly lower than more recent reports with Holstein cattle.

The researchers in the NAHMS study evaluated a number of different management and environmental variables; however, only two factors were statistically important to the variation they observed in colostrum quality (IgG concentration) – the source of colostrum and heat stresss index (temperature-humidity index).

Prepartum effects on colostrum IgG concentration are not well defined. The NAHMS study indicated that colostrum collected when the average temperature-humidity index (**THI**) indicated heat stress for cows during the month prior to calving produced colostrum with *greater* IgG concentration than cows with THI in the thermoneutral zone. The authors hypothesized that heat stress caused vasodilation in the udders of cows during colostrogenesis (final 3 weeks prior to calving), allowing more IgG to pass into the udder during colostrum formation. However, other research in the literature do not support this finding. Morrill et al. (2012) reported that colostrum collected from farms in the summer months in the southern U.S. had lower IgG concentrations compared to colostrum collected from farms in the Northern U.S. Also, Tao et al. (2012) reported that cows that were exposed to heat stress in Florida produced colostrum with the same IgG concentration compared to cows at the same facilities that were cooled. Thus, the idea that heat stress might improve colostral IgG concentration as concluded by Shivley et al. (2018) requires further evaluation. Also, others (e.g., Dunn et al., 2017) have shown that prepartum feeding and environment during dry period have little effect on colostrum IgG concentration.

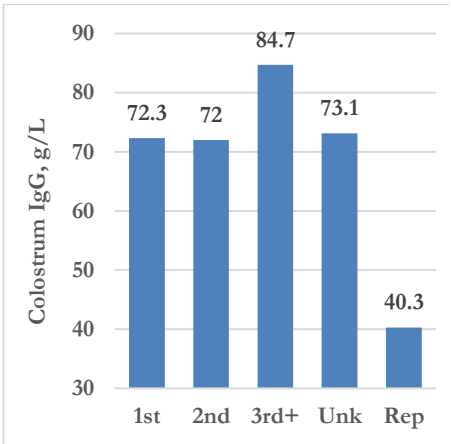

Figure 2. Colostrum IgG concentration from cows in 1st, 2nd or 3rd or later lactations, unknown samples or colostrum replacer. From Shivley et al., 2018.

The NAHMS study also concluded that colostrum from third or later lactation cows had higher IgG concentration compared to younger cows, colostrum replacers or pooled / unknown sourced colostrum (Figure 2). This finding is consistent with many other studies in the literature that have reported that colostrum from younger cows (1st and 2nd lactation) is generally lower in IgG concentration that colostrum from older cows. It is noteworthy, however, that the average colostrum from first lactation cows averaged 72.3 g/L – well above the target of 50 g/L we think of as good quality colostrum. Thus, it makes sense to

routinely test colostrum with a refractometer and consider using colostrum from first lactation animals if it is satisfactory in IgG concentration.

The NAHMS authors reported that there was no significant difference between Western and Eastern samples in colostrum quality. This differs from the research from Morrill et al. (2012), which reported that colostrum from cows in the Southwest (CA, AZ, TX) was lower in IgG than from cows in the Midwest or Northeast.

Serum IgG Concentration

NAHMS researchers also collected blood from 1,623 Holstein heifer calves. Average serum IgG was 21.6 g/L (SE = 0.25) and 73.3% of calves had IgG concentrations ≥15 g/L. Calves with IgG concentrations <10 g/L (considered as *failure of passive transfer*) were reported in 12.1% of calves.

That a large majority of calves had serum IgG concentration ≥15 g/L is great news. Calves with sufficient IgG (>10 g/L; considered *successful passive transfer*) are less susceptible to getting sick and dying. Achieving high serum IgG concentrations is the ultimate goal of every good colostrum program – it is why we carefully collect, process and handle colostrum. It's also why we feed early (within 1 hr of birth if possible) and we feed enough to provide the calf with 150-200 grams of IgG in the first 24 h of life. These data suggest that, in the U.S., processes are more often in place that improve the management of colostrum.

It should be noted that these data are specific to heifer calves – the researchers did not include data for bull calves in their analysis, data of breeds other than Holstein. Including serum IgG from bull calves would likely reduce the overall averages.

The research team also looked at factors that affected the acquisition of immunity (i.e., serum IgG) in the young Holstein calves. The factors that were statistically important to the variation in serum IgG concentration in this dataset were region, pasteurizing, source of colostrum, age at feeding, volume fed, age at blood sampling and colostrum IgG

Region. Serum IgG was higher in the western region were region (23.5 and 21.5 g of IgG/L of serum, respectively for western and eastern parts of the U.S. The reason for this difference is unclear, as colostrum IgG concentration did not vary according to region of the country in the NAHMS study. It's possible that differences in feeding practices or colostrum handling on western dairies could be responsible for the increased serum IgG

Pasteurizing. Serum IgG was higher for calves fed pasteurized colostrum compared to non-pasteurized colostrum (24.4 vs. 20.5 g/L, respectively). Quite a number of research studies have shown that serum IgG is improved when calves are fed colostrum that has been pasteurized. More information on pasteurization is available in Calf Notes #96 and #200.

Age at feeding. For each 1-h delay following birth to colostrum feeding, serum IgG decreased 0.32 g/L (SE 0.11). This finding is very consistent with the idea that, as calves age, their ability to absorb immunoglobulins declines until about 24 h of age, when that ability is lost. The process of maturation of the intestine is called "gut closure". The factors associated with gut closure are not completely known but involve (at least) the development of intestinal enzyme secretion, turnover of immature intestinal cells (which can absorb macromolecules) with mature cells that have lost the ability, and development of enzymes within the intestinal cells that digest IgG. This finding reinforces the belief that "earlier is better".

Source of colostrum. Serum IgG was the highest in calves that received colostrum from first-lactation dams (average = 25.7 g/L, SE = 1.11) and lowest for calves fed commercial colostrum replacer (average =16.6 g/L, SE = 2.21). Wait! While the colostrum replacer makes sense (the IgG

concentration of replacers was lower in this study than of the colostrum samples tested by the researchers), the finding that serum IgG from calves fed colostrum from first-lactation cows is counter intuitive. A quick look at Figure 2 shows that 1st lactation cows produced colostrum, on average, with the lowest IgG content. Why would their calves have the highest serum IgG concentration?

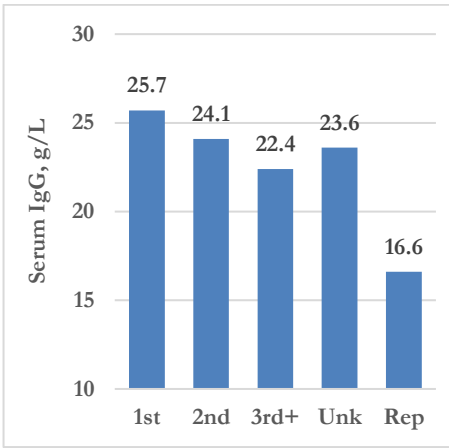

Figure 3. Serum IgG concentration in calves fed colostrum from cows in 1st, 2nd or 3rd or later lactations, unknown samples or colostrum replacer. From Shivley et al., 2018.

The answer is likely in the fact that, in general, first-lactation cows produce smaller calves. It's important to remember that the serum IgG concentration depends on the blood volume being measured – i.e., grams of IgG *per liter* of serum. Serum (or plasma) volume is a function of the body weight / size of the calf. If we put 50 grams of IgG into a calf with 3 L of plasma, it will have a higher serum IgG concentration (50 / 3 = 16.7 g/L) compared to the same 50 grams of IgG into a calf with 4 L of plasma (50 / 4 = 12.5 g/L). Smaller calves are more typical from smaller, first-lactation cows, so this explanation makes biological sense.

Volume fed. The authors reported that the more colostrum fed resulted in higher serum IgG concentration. Makes sense. There is, of course, an upper limit to the amount of colostrum we can or should feed to newborn calves – a good recommendation for a 40-kg newborn Holstein calf is to administer approximately 4 L (1 gallon) of colostrum in the first feeding (by esophageal feeder or nipple bottle) and offer (do not force-feed) a second feeding of 2 L at 12-h of age. Smaller calves (e.g., Jerseys) should be offered proportionally less colostrum (for example, a 25-kg Jersey calf could be fed 2.5 L in the first feeding, which is 10% of body weight).

Age at sampling. This is an interesting observation that has some practical implications to how we manage the program. The authors found that, as calves age beyond 24 h, their serum IgG concentrations decline linearly (about 0.7 g/L per day). This means that if I measure the serum IgG of calves at 10 or 15 days of age, the results I'm evaluating won't be correct. So, when is the best time to measure serum IgG? Generally, the closer to 24 hours (but AFTER 24 h), the better. We consider 24 h to be the age of gut closure. This is the age at which there is no longer absorption into the blood. However, the IgG in serum are not static – they are used to protect the body from disease-causing pathogens. Therefore, they are gradually used up and the serum concentration declines over time. Immunoglobulins will also leave the circulation and move into other parts of the body to protect it from pathogens. There isn't much change between 1 and about 5 days, so if you're measuring within that time frame, you're likely in good shape. Remember, too, that we're looking for large differences in serum IgG concentration. The tools that we use to monitor serum IgG on the farm (total protein refractometer or BRIX refractometer) are not perfect. Differences between, for example, 10.5 and 10.6 g of IgG/L of serum are not meaningful. However, difference between 15 g of IgG/L of serum and 5 g/L is meaningful.

Colostrum IgG. As we might expect, feeding colostrum with more IgG resulted in greater serum IgG in the calves. The authors reported that for every 10 g/L increase in colostrum IgG concentration, serum IgG in the calves fed that colostrum increased 1.1 g/L. This is an important take-away from the study. We know that colostrum IgG is remarkably variable – and it affects the ultimate goal of a colostrum program – calves with successful passive transfer. Therefore, monitoring colostrum

quality with a BRIX refractometer is an important management step in improving the health of calves. For more information on using a BRIX refractometer, see Calf Notes #183 and #199.

Summary

The NAHMS study provides a comprehensive look into the current state of calf raising in the United States. For the most part, the news is promising. Colostrum quality is higher than many previous reports and, on average, serum IgG concentrations are higher also. The proportion of heifer calves with FPT is on the decline, which is only good news for farmers and their calves. A key take-away from the data, however, is that there is still considerable variation in the acquisition of passive immunity. There are many variables in the overall equation are subject to significant variation, which needs to be managed using protocols. Implementation of clear, written, simple and consistent colostrum management protocols undoubtedly have helped in improving the state of calf raising in the U.S.

References

Abel Francisco, S. F., and J. D. Quigley, III. 1993. Serum immunoglobulin concentration in response to maternal colostrum and colostral supplementation in dairy calves. Am. J. Vet. Res. 54:1051-1054.

Dunn, A., A. Ashfield, B. Earley, M. Welsh, A. Gordon, M. McGee, and S. J. Morrison. 2017. Effect of concentrate supplementation during the dry period on colostrum quality and effect of colostrum feeding regimen on passive transfer of immunity, calf health, and performance. J. Dairy Sci. 100:357-370.

Gulliksen, S. M., K. I. Lie, L. Sølverød, and O. Østera. 2008. Risk factors associated with colostrum quality in Norwegian dairy cows. J. Dairy Sci. 91:704–712.

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. 27:176-180.

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.

Morrill, K. M., E. Conrad, A. Lago, J. Campbell, J. Quigley, and H. Tyler. 2012. Nationwide evaluation of quality and composition of colostrum on dairy farms in the United States. J. Dairy Sci. 95:3997–4005.

Shivley, C. B., J. E. Lombard, N. J. Urie, D. M. Haines, R. Sargent, C. A. Kopral, T. J. Earleywine, J. D. Olson, and F. B. Garry. 2018. Preweaned heifer management on US dairy operations: Part II. Factors associated with colostrum quality and passive transfer status of dairy heifer calves. J. Dairy Sci. 101:9185–9198.

Tao, S., A. P. A. Monteiro, I. M. Thompson, M. J. Hayen, and G. E. Dahl. 2012. Effect of late-gestation maternal heat stress on growth and immune function of dairy calves. J. Dairy Sci. 95:7128–7136.

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