Ruminal development in calves studied

Several times, I have been asked about good current information on functional development of the rumen in calves.

There are pieces of information available, and some good measurements and pictures of rumen papillae development in calves, such as at www.das.psu.edu/research extension/dairy/nutrition/calves/rumen. Until now, there has not been that defining, comprehensive study. A group from INRA and Universite de Toulouse in France has done such a study (Rey et al., 2012).

This study followed five male and one female Holstein calves from birth (day 1) to day 83, just before weaning. Their mean bodyweight was 86.8 ± 3.7 lb. Within two hours after birth, they were provided 2 liters of frozen-thawed colostrum. Until day 3, they were offered twice daily feedings of 1.5 liters of frozen-thawed colostrum (crude protein [CP] was 33.7 ± 7.1% of dry matter).

Calves were fed in a step-up and step-down program a 22.8% CP and 18.1% fat milk replacer reconstituted at 124 g powder per liter of 100°F warm water on the following schedule: 1.36 lb. for days 4-14, 1.65 lb. for days 15-21, 1.94 lb. for days 22-42, 1.65 lb. for days 43-49, 1.10 lb. for days 50-56 and 0.53 lb. for days 71-83.

All calves were allocated a pelleted starter (88.4% dry matter and 17.8% CP, 17.8% NDF, 10.2% ADF and 37.6% starch on a dry matter basis) and low-quality meadow hay (90.8% dry matter and 8.4% CP, 74.5% NDF, 45.1% ADF, and no detectable starch) at first, second and third month after birth of: 0.44 lb. and 0.13 lb., 2.64 lb. and 0.44 lb., 50, 55, 62, 69 and 83. These samples were taken via a stomach tube, which was sterilized before use, at 1 hour after the morning milk replacer meal and just before distribution of hay and starter. Appropriate sample handling and analyses are detailed in the Journal of Dairy Science paper.

Calves consumed all milk replacer fed. Daily starter dry matter intakes by periods (Table) explained 83% of total variance. Daily hay dry matter intakes by periods (Table) explained 52% of total variance. Note that starter dry matter intake was approximately 10 times hay intake.

Some rumen fermentation parameters are shown in the Figures. The evolution of rumen pH (Figure 1) was divided into three periods of days 1-9, days 10-40 and days 43-83. This explained 32% of total variance. The redox potential started highly positive, but then rapidly declined to about 1.25 for the remainder of the 83-day period. Butyrate concentrations increased over the first 10 days but then leveled off for the remainder of the 83-day period. Since butyrate has the greatest effect on functional development of rumen papillae, this may have been associated with other parameters indicating slow functional ruminal development in this study.

Rumen ammonia-nitrogen (Figure 2) would have simplified the feeding program and avoided the need and somewhat confounding effect of feeding hay. Milk replacer was fed twice daily at 0800 and 1600 hours, and hay and starter at 0900 and 1700 hours. Daily intakes were recorded for each calf.

Rumen samples were taken daily between day 1 and day 10, and additionally at days 12, 15, 19, 22, 26, 29, 33, 36, 40, 43, 47, 50, 55, 62, 69 and 83. Some rumen fermentation parameters indicating slow functional ruminal development in this study.

Bottom Line

With Al Kertz*

Some rumen fermentation parameters such as pH, ammonia-nitrogen, butyrate and other VFAs can be measured in young calves. The main differences are the level and range of pH. In this study, rumen pH ranged from 5.5 to 5.8. However, minimum values were 5.4, 5.5, 4.8 and 4.9, respectively. Monitoring rumen pH 24 hours per day yielded duration in time of rumen pH less than 5.8 at 100 minutes and 237 minutes; and from 784 minutes to 875 minutes, respectively. In Laarman et al. (2012), duration of rumen pH less than 5.2 also resulted in experiments when I was at Purina, and they were generally around the mid 5 range. Recent reports show similar low to mid 5 pH ranges.

In the study by Porter et al. (2007), calves on an all-pelleted starter had a rumen pH of 5.0 versus 5.4 for a well-texturized starter. In the study by Khan et al. (2011), calves on a poorly-texturized starter had a rumen pH of 5.1 versus 5.5 for the same starter, but with hay provided in addition. Thus, it appears that rumen pH in young calves should not be below about 5.5.

In other more recent studies (Laarman and Oba, 2011; Laarman et al., 2012), mean rumen pH of calves on different dietary treatments were 6.3, 6.4, 5.7 and 5.8. However, minimum values were 5.4, 5.5, 4.8 and 4.9, respectively. Monitoring rumen pH 24 hours per day yielded duration in time of rumen pH less than 5.8 at 100 minutes and 237 minutes; and from 784 minutes to 875 minutes, respectively. In Laarman et al. (2012), duration of rumen pH less than 5.2 also resulted in 143-403 minutes per day.

Rumen volatile fatty acids (VFAs) were not present at day 1, but progressively increased for the first 15 days, leveled off from day 15 to day 30 and then increased until day 60 followed by a gradual decline until day 83 (Figures 3-4). Acetate, followed at a lower level by propionate, had a similar pattern as total VFA.

However, the acetate:propionate ratio was between 3 to 4 during days 1-10, but then rapidly declined to about 1.25 for the remainder of the 83-day period.

Dry matter intake (lb./day) of starter and hay

| Days 4-51 | 0.93 ± 0.17 |
| Days 52-69 | 4.61 ± 0.42 |
| Days 70-83 | 7.59 ± 0.58 |
| Days 4-30 | 0.12 ± 0.04 |
| Days 31-57 | 0.43 ± 0.11 |
| Days 58-75 | 0.79 ± 0.15 |
| Days 76-83 | 1.24 ± 0.23 |

Note that starter dry matter intake was approximately 10 times hay intake. Some rumen fermentation parameters such as pH, ammonia-nitrogen, butyrate and other VFAs can be measured in young calves. The main differences are the level and range of pH. In this study, rumen pH ranged from 5.5 to 5.8. However, minimum values were 5.4, 5.5, 4.8 and 4.9, respectively. Monitoring rumen pH 24 hours per day yielded duration in time of rumen pH less than 5.8 at 100 minutes and 237 minutes; and from 784 minutes to 875 minutes, respectively. In Laarman et al. (2012), duration of rumen pH less than 5.2 also resulted in experiments when I was at Purina, and they were generally around the mid 5 range. Recent reports show similar low to mid 5 pH ranges.


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rapidly increased during the first 10 days but then progressively declined for the 83-day period.

Somewhat similar patterns were present for xylanase and amylase. Ureolytic activity increased over the first 25 days and then declined for the remainder of the study period with considerable variation. Proteolytic activity increased progressively until about day 15, plateaued down by about 50% from there until about day 50 when it peaked up at day 55 before declining until day 70 when it increased somewhat until day 83.

Overall, the stages were:
- Devoid of rumen activity and parameters at day 1, but then increased up to day 10, most likely associated with establishment of bacterial populations. This would also be when solid feed intake was initiated and began to progressively increase.
- As dry feed intake progressively increased from day 10 to day 83, total VFA increased and pH decreased until about day 50.

The researchers speculated that the increase in rumen pH at or slightly above 6.0 after 50 days was associated with stimulation of rumination and salivation. It would have been helpful to have visual indications of this possibility. The pelleted starter would not have facilitated rumination, but hay intake could have.

In the study of Porter et al. (2007), calves on the well-texturized calf starter treatment were observed ruminating by four weeks of age and spent 21% of their time ruminating compared to calves on the pelleted calf starter treatment, which did not begin ruminating until week 6 and only spent 9% of their time ruminating.

**The Bottom Line**

In this study, the first 10 days of calf life was when various ruminal activities and parameters ensued and increased. Rumen fermentation parameters increased after this time, and were associated with increased calf starter and hay intake, with a ratio of about 10:1. There are indications that rumination may have been protracted because of the pelleted starter and relying on hay intake to stimulate rumination.

The level of hay intake would not likely have contributed to rumination until around day 50 or later. It would have been instructive to have had visual determination of initiation and proportion of time ruminating to associate with the pelleted starter and the lower quality meadow hay.

**References**


