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Calf Note 173 – Effects of rumen acidosis on digestion in calves

Introduction

In previous Calf Notes (170, 172), I proposed the idea that subacute ruminal acidosis (**SARA**) is prevalent in young calves during the rumen development process and this phenomenon reduces fiber digestion, increases risk of diarrhea, and, possibly, contributes to increased risk of health problems. I further suggested that physical form of the diet and choice of ingredients in starters and exclusion of forage might contribute to SARA.

I received an e-mail came from a colleague who pointed to the paper by Porter et al. as an example of the effect of SARA on digestibility as related to pelleted vs. texturized starters without the confounding effect of forage.

So, the purpose of this Calf Note is to look in depth at the research by Porter and others to determine effects of form of ration (pelleted vs. mash) and amount of fiber (low, high) on rumen development and incidence of rumen acidosis.

The Research

The study was conducted in two replicates (trials). In the first trial, 32 newborn Holstein heifers were obtained from local sale barns at about 3 days of age. On arrival, calves were placed in elevated crates (no bedding was used) and offered milk replacer. The amount offered increased from 272 g/d (0.6 lb) on arrival to 544 g/d (1.2 lb) from d 12 to weaning. Calves were weaned when they ate about 700 g/d for 4-5 d.

Ingredient	Low Fiber	High Fiber
Corn & cob meal	0.0	20.0
Cracked corn	33.8	0.0
Crushed oats	35.0	25.0
Beet pulp	0.0	16.0
Brewer's grains	0.0	10.0
Soybean meal (50%)	20.7	18.0
Molasses	7.0	7.0
Other ing.	4.0	4.0

Table 1. Ingredient composition of low and high fiber starters.

Two calf starters (**CS**) were formulated to contain low and high fiber (see Table 1). One half of each feed was pelleted and the other half was fed as a meal. Thus, there were a total of four feeds in the study. The nutrient content of the starters is shown in Table 2. Note that, although ingredients were similar for the respective fiber diets, nutrient content varied somewhat, probably due to the effects of pelleting(e.g., NDF was higher in pelleted vs. mash feeds). Pelleting reduced the particle size of each feed, also (Table 2).

Performance of calves is in Table 3. There are a couple of noteworthy items in the performance of these calves. Firstly, calves fed the mash diets ate more CS from 5 to 8 wk and, as a result, grew faster. It's important to note that the particle size of the mash diets was larger than pellets – this diet was not a finely ground meal type starter. The mean particle size of the mash diets was 2,014 µm, or about 2.0 mm in length. This was sufficient to promote earlier rumination – calves fed the mash form started ruminating at 3.7 wk of age compared to 6.0 wk of age for calves fed pellets.

The second item to notice in the results is the fecal scores of calves. The fecal score reported by the authors is the number of instances that calves had loose or semi-loose feces during the 8-wk trial. Calves fed the high fiber mash diet has fewer instances of loose feces compared to calves fed the low fiber mash or the high fiber pellet.

Next, note the average daily gains of calves. During the first 4 wk of the study, calves gained <200 g/d. Using ADG to calculate overall growth, we calculate that the calves (averaged across treatments) started the study at 39.3 kg (87 lb) and ended at 59.8 kg (132 lb). Clearly, the calves fell far below the goal of doubling their birth BW by two months of age. Several factors could account for relatively poor rates of ADG, including colostrum status (although serum TP on arrival was not reported), stress of transport (calves were purchased from sale barns), low rate of CMR fed and, perhaps, rumen acidosis.

Nutrient	LF-P	LF-M	HF-P	HF-M	CMR
Dry matter, %	89.6	89.5	89.7	87.9	94.8
Crude protein, %	22.8	24.5	24.4	20.7	25.9
Crude fat, %	2.9	3.1	2.7	2.4	19.3
Ash, %	6.9	7.6	7.4	6.5	8.8
NDF, %	20.2	16.9	26.9	29.0	
ADF-N, %	2.2	1.7	3.2	2.7	
ME, Mcal/kg	2.71	2.88	2.54	2.73	
Mean particle size, µm	741	2,122	1,036	1,906	

Table 2. Nutrient composition of low fiber (LF) and high fiber (HF) pellets (P) and mash (M) starters.

Feed efficiency of calves from 0 to 8 weeks of the study was not reported by the authors (though they did report post-weaning efficiency), but we can calculate gain to feed ratio (**G:F**) using treatment means. If total BW gain is calculated (ADG × 56 d) and then divided by DM intake (CMR + CS), we can calculate how efficient these calves were. The average G:F ratio was 0.318 for all calves for the 0-8 wk period. This means that calves gained 318 grams for every kilogram of feed consumed. To put this into some perspective, other authors reported typical G:F ratios greater than 400 grams of gain per kilogram of DM intake (Bateman et al., Hill et al., 2007). On the other hand, highly stressed calves with high rates of failure of passive transfer have poor feed efficiency; some reports indicate that calves gain < 200 grams per kg of DM intake (Quigley and Wolfe, 2003). Protein quality can also affect G:F ratio (Quigley, 2002) and poorly digested proteins can reduce G:F from >400 g ADG/kg DM intake to <250 g/kg. Lesmeister and Heinrichs (2004) reported high G:F ratios (>450 g ADG/kg of DM) in calves fed starters containing different carbohydrate sources. It's noteworthy

Item	LF-P	LF-M	HF-P	HF-M
No. of calves	8	7	8	9
Initial BW	39.4	38.6	40.4	38.9
ADG, kg				
0-4 wk	0.14	0.16	0.13	0.19
5-8 wk	0.46[a]	0.59[b]	0.56[a]	0.59[b]
0-8 wk	0.30[a]	0.38[b]	0.34[a]	0.44[b]
CMR intake, kg	9.5	9.9	10.6	9.0
CS intake, kg				
0-4 wk	8.1	9.4	9.3	11.1
5-8 wk	38.3[a]	45.6[b]	39.5[a]	56.3[b]
0-8 wk	46.4[a]	54.5[b]	48.8[a]	667.4[b]
Weaning age, d	27	27	29	27
Feces score	4.3[ab]	6.6[b]	5.9[b]	1.7[a]

Table 3. Performance of calves fed low fiber (LF) and high fiber (HF) pellets (P) and mash (M) starters.

[a,b]Means within rows with different superscripts are different ($P < 0.05$).

that these calves were fed 4 L of colostrum within 12 h of birth, were not transported and were housed individually and isolated from other calves.

In trial 2, bull calves (n = 16) were raised in metabolism crates and digestibility of each diet was measured during wk 7-8. At the end of the 8-wk trial, the calves were sacrificed and rumen measurements were made.

Calves in trial 2 were fed the same diets and managed the same way as calves in trial 1, so results should be applicable to both groups.

Key results of trial 2 are in Table 4. Notice initially that fiber level (LF vs. HF) had large and significant effects on digestibility of most nutrients. Generally, calves fed high fiber diet had lower digestion of DM, fat, protein, and energy (TDN and ME). There were also effects of physical form – calves fed the mash feed generally had higher digestion of DM, fiber and energy compared to calves fed the pelleted ration.

Item	LF	HF	P	M
Digestibility, %				
DM	76.5[a]	71.1[b]	71.3[a]	76.3[b]
Ether extract	75.4[a]	67.9[b]	69.4[c]	73.9[d]
Crude fiber	26.6[a]	37.0[b]	23.7[a]	38.9[b]
Crude protein	79.7[c]	76.0[d]	77.5	78.2
TDN	74.5[a]	69.2[b]	69.5[a]	74.2[b]
NDF	46.1	45.4	39.7[a]	51.9[b]
ME	64.3[a]	60.4[b]	60.2[a]	64.5[b]
Rumen, pH	4.95	5.50	5.03	5.43
Papillae length, cm	2.9	3.5	2.9	3.5

Table 4. Digestibility and rumen parameters of calves fed low fiber (LF) and high fiber (HF) pellets (P) and mash (M) starters in trial 2. Main effects are presented only.

[a,b]Means within rows with different superscripts are different ($P < 0.01$) and [c,d] differ at $P < 0.05$.

So, what do these observations mean? It's clear that calves fed high fiber rations (28% NDF) had lower nutrient digestion compared to calves fed lower fiber in their rations (19% NDF). One potential reason (among others) is that when calves suffer from rumen acidosis, their ability to ferment fiber in the rumen is impaired, and, thus, digestion is reduced. Further, pelleted diets with very small particle size move more quickly out of the rumen, so the rumen bacteria have less time to ferment the carbohydrates to produce VFA. As can be seen from Table 4, rumen pH of all calves was very low – at or below 5.0. Clearly, in this experiment, rumen fermentation would have been impaired, if we assume that rumen bacteria in the young rumen are equally sensitive to rumen pH as are the bacteria in rumens of older animals. Thus, it is possible that higher fiber rations (which could be more sensitive to depressions of rumen pH) could be less well fermented in calves with SARA. Further, passage rates of diets that were pelleted would be faster, thus exacerbating the depression of digestibility.

Could the differences in digestibility be associated in some way with rumen pH? In both cases (high vs. low fiber and pellet vs. mash), there were statistical differences in digestibility and no statistical difference in rumen pH, which suggests that differences in physical form and fiber level were not associated with SARA. On the other hand, if calves did NOT have SARA, it's possible that rumen fermentation would be more complete and nutrient digestibility would have improved in calves fed high fiber and pelleted diets. However, this theory requires additional research to prove or disprove.

Another way to look at these data are to compare them with other published research on nutrient digestion. In Table 5, I summarized several published studies of digestibility in calves fed various diets. As you can see, there are quite a number of studies and <u>lots</u> of variation. Generally, however, it appears that some of the means in the study by Porter et al. are lower than the average and may suggest that calves in this study had lower digestion than would be expected under "normal" conditions. However, a meta-analysis would be necessary to confirm this observation.

Summary

The data by Porter et al. indicate that differences in physical form and fiber level of starters can affect digestion of calves from 7-8 weeks of age. However, in this study, the rumen pH suggests that all calves suffered from SARA for at least a part of the day (when samples were taken). The observed pH were quite low, suggesting that SARA was a considerable issue in the study.

Fiber digestion at low rumen pH is impaired; this can shift the site of digestion from the rumen to the intestine, which can alter nutrient availability and animal performance. High fiber and pelleted form of starter may exacerbate the issue by increasing rate of fermentation (pellets), decline in rumen pH and increased rate of outflow from the rumen.

Producers can improve the digestive efficiency of calves fed highly fermentable starters by ensuring regular consumption throughout the day (i.e., make sure feed is always available), providing an adequate supply of free water, sufficient bunk space (if calves are housed in groups), and ensuring that calves have sufficient passive immunity to avoid disease and get off to a good start.

A future Calf Note will evaluate the role of feed additives to minimize the effects of SARA in calves.

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Written by Dr. Jim Quigley (31 March 2013)

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	Porter				Khan				KHORASANI		Gomez				Gomez			Gomez	
	LF	HF	Pellet	Mash	Barley	Corn	Oats	Wheat	SBM	CM	L,C	LAO	H,C	H,AO	C	SC	A0	C	A0
DM	76.5	71.1	71.3	76.3	71.0	72.0	72.0	71.0	81.8	75.5	72.6	72.4	67.8	71.2	66.1	66.8	66.7	63.8	67.9
CP	79.7	76.0	77.5	78.2	75.0	76.0	75.0	76.0	73.7	66.1	67.9	69.9	74.4	73.5	69.5	72.3	71.8	74.1	76.1
NDF	46.1	45.4	39.7	51.9	43.0	41.0	42.0	40.0			50.2	54.8	66.8	67.3	47.5	51.3	50.2	39.6	47.0
DE	75.6	70.5	70.6	75.4	72.0	71.0	73.0	71.0											
Starch					89.0	89.0	87.0	87.0											
NFE	81.9	77.1	77.4	81.6															
TDN	74.5	69.2	69.5	74.2															
ADF	33.8	38.3	28.8	43.2							34.1	38.5	52.1	51.9	18.0	32.2	32.8	21.3	30.0
CF	26.6	36.0	23.7	38.9															
ME	64.3	60.4	60.2	64.5															
EE	75.4	67.9	69.4	73.9															
OM											74.6	74.2	74.7	72.9	67.1	69.5	69.2	66.0	69.3

	Cummins									Hill				Overall			
	30GR	30CH	30CN	45GR	45CH	45CN	60GR	60CH	60CN	A	B	C	D	Avg	SD	Min	Max
DM	69.5	61.4	84.8	61.4	58.7	83.2	58.7	74.3	81.5	75.6	78.3	78.7	67.3	71.3	4.3	63.8	81.8
CP	62.5	64.5	74.5	48.4	45.1	74.5	56.5	68.2	73.1	72.4	72.3	74.1	71.8	73.8	3.5	66.1	79.7
NDF														48.5	8.4	39.6	67.3
DE														72.4	2.1	70.5	75.6
Starch														88.0	1.2	87.0	89.0
NFE														79.5	2.6	77.1	81.9
TDN														71.9	2.9	69.2	74.5
ADF														35.0	10.1	18.0	52.1
CF														31.3	7.3	23.7	38.9
ME														62.4	2.4	60.2	64.5
EE										70.3	75.4	76.3	75.4	71.7	3.6	67.9	75.4
OM										77.4	78.3	78.7	68.0	70.8	3.3	66.0	74.7

Table 5. Percent digestibility of nutrients (%) from calves fed various experimental treatments. For specifics on each treatment, see respective journal article.