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Calf Note 168 – Where does the protein go?

Introduction

Colostrum is special stuff. The composition of maternal colostrum (MC) is profoundly different from that of milk; it's so different in fact, we call secretions from the mammary gland in the first 24 hours after parturition something different from "milk". Colostrum contains large amounts immunoglobulins (**Ig**), particularly IgG, obtained from the cow's bloodstream during the last few weeks of gestation. In addition, it contains many other proteins, including hormones, enzymes and growth factors that may influence the metabolism of the newborn calf. Also, large amounts of fat, vitamins and minerals support the calf's nutritional needs immediately after birth.

Item	Colostrum	Milk
Solids, %	22.6	12.5
Protein, %	12.7	3.2
Fat, %	5.6	3.7
Lactose, %	2.9	4.9
IgG, g/L	68.8	0.1

Table 1. Composition of first milking-colostrum (adapted from Morrill, et al., 2012) and whole milk.

Table 1 compares the composition of first-milking MC to that of whole milk. As is abundantly clear, MC is thicker and contains much more solids and total nutrient than milk.

So what happens when the calf consumes a meal of MC? Let's say that a calf is fed a meal of the recommended one gallon of colostrum (3.8 L) in the first hour after birth. What type of nutrient load are we providing to the calf? And, what happens to those nutrients? Table 2 compares a meal of one gallon (3.8 L) of MC with one gallon of whole milk.

A calf consuming a meal of 3.8 L of MC containing 12.7% protein will consume a total of 480 grams of protein. This compares to an intake of 121 grams of protein when a calf drinks a similar amount of whole milk. A large meal of MC provides about 4X the protein than a similar meal of milk!

Item	Colostrum	Milk	%
Intake, ml	3,780	3,780	0
Solids, g	854	473	181
Protein, g	480	121	397
Fat, g	212	140	151
Lactose, g	110	185	59
IgG, g	260	0	…

Table 2. Intake of nutrients by calves fed one gallon (3.8 L) of colostrum or whole milk.

Of course, our goal is to provide IgG to the newborn calf so it is protected against pathogens in the environment. But what happens to the rest of the protein? It's an interesting observation and may provide some insights into the newborn calf's metabolism.

We can monitor how well the newborn absorbs IgG by calculating a statistic called apparent efficiency of IgG absorption, or AEA. This tells us how efficiently the IgG in colostrum fed is recovered in the bloodstream after 24 hours of age. To calculate this statistic, we need to know the body weight of the calf (to estimate the blood volume), plasma (or serum) IgG at 24 hours and how much IgG the calf consumed. The equation is:

AEA (%) = IgG in plasma (g/L) x Plasma volume (L) ÷ IgG intake (g)

We typically estimate plasma volume using BW:

AEA (%) = IgG in plasma (g/L) x [BW kg x 9%] ÷ IgG intake (g)

So, a calf with 12 g/L of IgG, weighing 40 kg and having consumed 150 grams of IgG absorbed the IgG with an efficiency of:

AEA (%) = 12 x [40 x 0.09] ÷ 150 = 0.288, or 28.8%

Typically, AEA of IgG will range from 20 to about 35% (Quigley and Drewry, 1998).

If IgG are absorbed at 28% efficiency, what about the other proteins? Can we calculate the AEA for the non-IgG proteins? Well, the answer to this question is yes, but first we need a little more information.

Calves are born without circulating IgG, but they have non-IgG proteins in their bloodstream. A newborn calf will have somewhere around 4.0 g/dl (40 g/L) of proteins in its bloodstream immediately after birth. These proteins include transport proteins, albumin, and many others. There are none (or very few) IgG, however.

To calculate what happens to non-IgG proteins we need to estimate how much total protein is in the bloodstream at birth – not only in terms of the concentration (i.e., 4.0 g/dl), but in terms of total grams of protein. We can estimate this on the basis of the plasma volume, but, unfortunately, plasma volume is dynamic. That is, plasma volume at 24 hours (which we assume is about 9% of BW based on published research, see Quigley et al., 1998) is not the same as plasma volume at birth. When calves drink a meal of colostrum, plasma volume increases. So, immediately at birth we assume that the plasma volume is something less than 9%. Some estimated plasma volume at birth to be closer to 7% of body weight.

If we have a blood sample at birth to measure total protein, we can also measure hematocrit or packed cell volume. We make the assumption that, even though plasma volume increases with colostrum consumption, there is little change in the total amount of cells in the circulation (NOTE: this assumption is almost certainly incorrect, but the degree of error should be small in terms of the calculations we're doing).

Have a look at Table 3. These are data from a group of calves fed 3.8 L of MC (Hammer et al., 2004). At 24 hours of age, calves weighed 49.4 kg and had a PCV of 33.19%, and a serum total protein and IgG concentration of 6.15 g/dl and 18.1 g/L, respectively. We assume they had a PV of 9% at 24 hours of age. Therefore, their total PV (in liters) was 4.45 L. Using the PCV statistic, we estimate the amount of packed cells was 2.21 L.

Assuming the total amount of packed cells didn't change (2.21 L at 0 and 24 hours of age) from 0 to 24 h, we can then calculate the amount of plasma and total blood volume in the calf. The amount of total protein in the calf's blood at birth was 4.75 g/dl (47.5 g/L; Table 3) and at 24 hr it was 6.12 g/dl (61.2 g/L). The net change in total protein was 13.7 g/L, which was due to the absorption of IgG and other proteins.

We can then calculate the number of grams of protein in the blood of the calf at birth and 24 hours. In Table 3 we see that the calf had 156.5 grams of protein in the blood; this increased to 272.1 grams at 24 hours. The next change was an increase of 115.6 grams. Calves consumed 494 grams of total protein from colostrum, so 115.6 / 494 = 23.4% efficiency. So, we were able to recover about 23% of the protein the calves ingested in the blood at 24 hours of age.

Item	0 hr	24 hr	Change	AEA
BW, kg	45.6	49.4	3.8	
PV, %	7.2	9.0	0.9	
PCV, %	40.14	33.19	-6.95	
Total blood, L	5.50	6.65	1.15	
PV, L	3.29	4.45	1.15	
PCV, L	2.21	2.21	0.0	
Total protein, g/L	47.5	61.2	13.7	
IgG, g/L	0.0	18.1	18.1	
Total protein, g	156.5	272.1	115.6	23.4
IgG, g	0.0	80.5	80.5	28.5
Non-IgG, g	156.5	191.5	35.2	16.6

Table 3. Protein dynamics in calves fed maternal colostrum. Data from Hammer et al., 2004.

We do the same math with IgG (80.5 grams in the plasma at 24 h / 282 g of intake = 28.5% efficiency) and the non IgG proteins, which are calculated by difference (35.2 g / 212 = 16.6% efficiency).

It's noteworthy that the non-IgG fraction is absorbed with lower efficiency – compared to IgG, which were absorbed with about 29% efficiency, the non-IgG protein fraction was absorbed with only about 17% efficiency. So, where did all the other protein go?

Though we assume that many colostral proteins escape intestinal digestion, some research suggests that at least some digestion occurs in the intestine in the first 24 hours. Yvon et al. (1993) reported that a large portion of protein from α-lactalbumin is digested in the abomasum and small intestine in newborn lambs. Thus, there does appear to be digestion of some proteins in the intestine, which means that some proteins are digested to individual amino acids, which may be used for protein synthesis or glucose production. Immunoglobulins are more resistant to digestion, however.

The non-IgG proteins (and some IgG) may also be metabolized by the muscle and liver for glucose production which then may be used for thermoregulation and other functions. Other circulating proteins may be used by the body for protein synthesis and thus will leave the bloodstream. Finally, some protein is filtered by the kidney and excreted in the urine. This condition, called proteinuria, is common in young calves.

It appears that if we increase the amount of non-IgG protein ingested, the less efficiently that protein is used. Davenport et al. (2000) fed calves a colostrum supplement with the addition of 0, 200 or 400 grams of casein or whey protein. Table 4 shows that, as the amount of non-IgG protein intake is increased, the AEA of the non-IgG fraction is depressed. Calves fed 400 g of added casein or WPC had 2.1 and 7.8% AEA of the non-IgG fraction, respectively. This suggests that there may be a maximum amount of protein that the calf can handle. Table 5 shows the estimated mass of protein (total, IgG and non-IgG proteins) in the plasma at 24 hr of age. It appears that the additional protein fed to the calves was metabolized and utilized for energy, or perhaps it was excreted by the body. Davenport et al. (2000) also reported increased urea N concentration with added protein, suggesting that at least some of the non-IgG protein they fed was metabolized by the body.

Added product	Total	IgG	Non-IgG
	AEA, %		
0 g	26	29	24
200 g casein	12	28	8
400 g casein	4	19	2
200 g WPC	19	34	14
400 g WPC	12	31	8

Table 4. Apparent efficiency of absorption for calves fed a colostrum supplement plus 0, 200 or 400 grams of casein or whey protein concentrate (WPC). Data from Davenport et al., 2000.

Summary

Calves fed colostrum in their first feeding, particularly when we feed 3.8 L, ingest a huge mass of protein – probably more than at any other time in their lives. Some of this protein is digested to amino acids and small peptides in the gastrointestinal tract. Some protein will be absorbed intact; these proteins may be metabolized to amino acids or it may be excreted in the urine if circulating levels of protein are too high.

Added product	Total	IgG	Non-IgG
	Grams in plasma at 24 h		
0 g	160	20	144
200 g casein	158	20	138
400 g casein	138	13	124
200 g WPC	176	25	152
400 g WPC	167	22	142

Table 5. Estimates of the total mass (grams) of protein in blood of calves 0, 200 or 400 grams of casein or whey protein concentrate (WPC). Data from Davenport et al., 2000.

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