Rumen Transition from Weaning to 400 Pounds

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KEYWORDS

• Rumen development • Weaned calf • Rumen papillae • Ruminal VFA production

KEY POINTS

- Rumen size changes dramatically from weaning 200 pounds (91 kg) to 400 pounds (181.8 kg) body weight.
- Rumen substrate is very influential to rumen development.
- Rumen papillae development is most important to rumen nutrient absorption.
- Grain is superior to forage in developing rumen papillae.
- Rumen size does not indicate papillae development.

INTRODUCTION

The average age at weaning in the United States is 9 weeks.[1] The actual age at cessation of milk feeding may be anywhere from 6 to 8 weeks, but the act of weaning usually implies a departure from the "nursery" facility and into a facility with small 8- to 12-head groups. Although the purpose of this article evaluates nutritional management to optimize rumen development, the importance of group size management to reduce stress and the incidence of bovine respiratory disease at weaning cannot be over emphasized. An 8- to 12-head group is ideal,[2,3] but groups of 20 weaned calves can be managed if pen space, bunk space, and water availability are optimal. An artfully formulated nutrition program cannot overcome poor management decisions. Water intake management is crucial to rumen development and fermentation.[4] Weaned calves have experienced individual feeding with a bucket of water and feed available to them at all times. They will be placed into a group pen with an automatic waterer they have never used and may not be able to locate. Some sort of supplemental water supply, such as an in-pen open top tank, is advisable until all the calves are consuming water.

PROMOTING RUMEN PAPILLAE DEVELOPMENT

The preweaning feeding program is important to create ideal rumen papillae development,[5,6] as illustrated by these photos from Penn State University[7] (**Figs. 1–3**). Calves

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Fig. 1. Impact of preweaning diet composition on rumen papillae development. (Photos courtesy of Penn State Extension.)

fed milk or milk replacer as the sole diet and calves fed milk or milk replacer with hay do not develop rumen papillae quickly. Calves fed milk or milk replacers, with a starter feed, do develop rumen papillae, and they do so by 4 weeks of age. **Fig. 3** is a photograph of a 4-week-old calf rumen with good rumen papillae development, whereas **Figs. 1** and **2** are photographs of 12-week-old rumens with little to no rumen papillae development. Diet composition is important to rumen papillae development.

RUMEN SUBSTRATE EFFECT ON RUMEN DEVELOPMENT

Preweaning grain intake produces development of the rumen papillae.[8] There is a misconception that calves should be offered hay during preweaning management. Although the volume of the rumen as a percent of the 4 stomach compartments is essentially doubled by 8 weeks (**Table 1**), most rumen papillae development is a direct result of preweaning grain intake.[8] Adding a source of dietary structural carbohydrates into the preweaning diet limits rumen papillae growth and density.[9]

Preweaning rumen papillae growth and development determines the health of the rumen as well as the efficiency of rumen fermentation postweaning. A functional rumen at 8 weeks of age has volume limitations in providing for optimal and economic growth of the calf. It takes 2 to 4 weeks for specific classes of bacteria to populate the rumen and begin to efficiently ferment the structural carbohydrates in hay.[10] Research has demonstrated that diets can be fed containing 0%, 7.5%, and 15% of the dry matter diet as processed roughage in light calves.[11] However, this research controlled particle size, offering a smaller particle size (0.3–0.75 inches or 8–19 mm) than what

Fig. 2. Impact of preweaning diet composition on rumen papillae development. (Photos courtesy of Penn State Extension.)

is provided to most calves through 400 pounds (181.8 kg) in the field. This particle size would need less further mastication to provide adequate surface area for bacterial fermentation. These researchers proved that coarse grain was superior to ground grain with regard to all rumen characteristics and volatile fatty acid (VFA) production. They also concluded that butyrate and propionate were superior to acetate for papillae growth, which supports a preference for a grain-based as opposed to a forage-based diet.

RUMEN VOLUME AND ESTIMATED INTAKE

Assuming a rumen volume illustration of 1 gallon (3.79 L), this volume can accommodate 6 pounds (2.73 kg) of grain mix or 1 pound (.45 kg) of hay. The potential energy availability difference between these 2 feedstuffs is obvious simply due to rumen volume limitations. Butyrate and propionate are the primary VFAs produced from grain. Acetate is the primary VFA produced from hay. Acetate retards rumen papillae growth and development, giving a significant advantage in rumen fill volume to a grain-based diet for preweaned and postweaned calves. Rumen papillae length is considered the most important factor to rumen development in small ruminants.[12]

It is appropriate to feed as much grain mix as the calves will eat preweaning and postweaning. In general, around 3% of body weight on an as-fed basis is provided each day. For dairy beef calves, maintain the level of intake through 400 pounds (181.8 kg) of body weight. Replacement dairy heifers are limit fed to produce 2 to 2.5 pounds (0.91–1.14 kg) of body weight gain per day. A small amount of high-

Fig. 3. Impact of preweaning diet composition on rumen papillae development. (Photos courtesy of Penn State Extension.)

quality roughage is provided around 300 to 350 pounds (136.4–159 kg) of body weight. When replacement dairy heifers reach 400 pounds (181.8 kg), moderate the energy levels in their diets to avoid excessive fat deposition in the udder. The goal is to manage replacement dairy heifer diets to produce adequate daily gain without depositing excess body fat. Monitoring dry matter intake for replacement dairy heifers to include higher roughage levels is a good indicator of diet adequacy. Adapting to fiber first and then introducing ensiled feedstuffs, preferably after 400 pounds (181.8 kg) body weight, is recommended. As always, evaluating weight and hip height appropriateness for age is crucial. A more detailed discussion of proper diet transition procedure from all grain diets to an age-appropriate total mixed ration (TMR) for these light calves is presented in another section of this article.

Table 1
Impact of age on percent volume of stomach compartments

%	0 wk	8 wk	12 wk
Reticulorumen	38.0	61.2	67.0
Omasum	13.0	13.4	18.0
Abomasum	49.0	25.4	15.0

From Review of strategies to promote rumen development in calves. *Animal* 9 (8): 490; Diao, Zhang and Fu. 2019

Table 2
Effect of percent hay in dry matter diet on performance of 12-week-old calves

Concentrate lb/d	1	2	3	4	5
% Hay DMB	61	31	28	16	4
ADG lb/d	.70	.92	1.03	1.32	1.30
Live wt lb/hd	130	139	132	172	170
Rumen papillae, mm	4.2	5.2	5.5	7.4	7.4
% of Live Weight					
Reticulorumen	18	15	14	11	10
Alimentary tract	23	20	19	15	14

Abbreviation: DMB, dry matter basis,

DIET COMPOSITION EFFECT ON PERFORMANCE AND RUMEN PARAMETERS IN LIGHT CALVES

Much of the research done on immature rumen development was published in the 1950s and 60s.[13–17] It is warranted to refresh the data set with today's genetics and additives that may alter some of these tried and true principles.[18]

A. F. Kertz presented a concise summary of some of this historical research in an article in Progressive Dairy, January 13, 2021.[19] He referenced published peer-reviewed research that concluded grain intake stimulates rumen papillae development, and the scratch factor of fiber feeds may increase rumen size, but does little to increase papillae, and therefore nutrient absorption, in ruminants up to 12 weeks of age. The following is a summary table he referenced in this article (**Table 2**).

There was a question raised by Dr Kertz regarding gut fill. For calves this small with this wide variation in hay intake, the influence of gut fill probably makes the true body weight and corresponding average daily gain differences even greater. In future research, an attempt to correct for this factor should be considered.

ANECDOTAL PRESENTATION OF ACTUAL PERFORMANCE IN A COMMERCIAL CALF GROWER OPERATION

The following is a summary of 2 years of calf ranch data, collected from the field by this investigator. The field study facility is a well-managed operation that uses a whole-grain, coarse grain program with no hay feeding. The only roughage intake is from the bedding in the barns. This bedding was run through a forage processer so its utilization may support previous reported forage processing research.[11] Each year represents 5 groups of 340 hutch calves from weaning, 9 weeks, to 400 pounds (181.8 kg) (**Table 3**).

These data are presented to allow for economic analysis for current ingredient costs of this high-grain diet versus a lower cost, high-roughage diet. Once calves reach this

Table 3
Two year's calf ranch summary performance data (9 weeks to 400 pounds)

Head In	Head Out	In Wt	Out Wt	DOF	ADG	F/G	Daily Feed
1680	1676	209	416	68	3.05	3.26	9.93
1673	1668	201	423	71	3.13	3.27	10.26

Abbreviations: DOF, days on feed; ADG, average daily gain; F/G, feed to gain ratio.
All units in pounds; daily feed-as fed.

stage, rumen development is complete, and the attending nutritionist is tasked with formulating diets that promote optimal rumen microbe populations, balanced against the economies of feeding cattle.

EXAMPLE DIETS AND TRANSITION STRATEGIES FOR YOUNG RUMINANTS

Table 4 illustrates 2 grain mixes composed of whole corn and a commercial protein supplement pellet. The mix containing 600 pounds (272.7 kg) of pellets and 1400 pounds (636.4 kg) of whole corn is for calves weighing 200 to 250 pounds (113.6–159 kg). The mix containing 500 pounds (227.3 kg) of pellets and 1500 pounds (681.8 kg) of whole corn is for calves weighing 250 to 350 pounds (113.6–159 kg). As mentioned previously, the intakes are approximately 3% of body weight as fed.

There is a much more detailed nutrient analysis available, but it is not pertinent to this consideration. Dry matter, protein, and Net Energy (NEm [maintenance] and NEg [gain]) are the primary considerations in proper ration transition for rumen stability. The macro- and microminerals as well as vitamins are balanced to meet or exceed National Research Council requirements.[20]

To illustrate the 3% of body weight as-fed intake, a 250 pounds (113.6 kg) calf will consume approximately 2.5% of its body weight on a dry matter basis each day. Therefore, 250 pounds (113.6 kg) X .025 = 6.25 pounds (2.84 kg) of dry matter. Next, divide 6.25 pounds (2.84 kg) dry matter by 86% dry matter in the diet, which yields 7.26 pounds (3.3 kg) as fed. The same procedure can be applied to each weight break of diet assignment. Most of these calves are fed in well-bedded barns where bedding intake prepares the rumen to begin developing bacteria that digest fiber. As the calf intake grows, this moderate amount of fiber digesting bacteria helps promote a stable rumen with regard to pH. The dietary management of calves housed in facilities without bedding, that is, slatted floors or sawdust or sand bedding, present a challenge, as fiber will need to be incorporated in the diet formulation. Processed hay or straw at 7.5% to 15% of the diet should be considered.[11]

TRANSITION STRATEGY FROM A GRAIN MIX TO A TOTAL MIXED RATION

Shown here are 3 TMRs to transition calves from the grain mix to a TMR. The first TMR is to accustom the calf to a higher moisture diet as well as another protein and energy

Table 4
Two age-specific grain-based diets, whole corn/commercial pellet (32% protein) grain mix expressed in pounds per ton

Ingredient	200–250 pounds Body Wt	250–350 pounds Body Wt
Whole corn	1400	1500
32% CP pellet	600	500
Nutrient Analysis (Dry Matter %)		
Dry matter%	86.50	86.25
Crude protein%	16.60	15.19
Crude fat%	3.12	3.24
NEm Mcal/cwt	93.82	95.10
NEg Mcal/cwt	63.62	64.72
Ca %	.89	.75
P %	.56	.52

Table 5
Formulations for a total mixed ration feeding program in percentages of total diet

Ingredient	TMR 1	TMR 2	TMR 3
Balancer	1.55	1.60	1.48
Grass hay	12.72	8.83	.60
Corn silage			25.00
Cracked corn	43.91	28.23	28.73
High-moisture ear corn		25.00	14.36
Modified distillers grain	41.82	36.34	29.83
Nutrient Analysis (DM%)			
Dry matter %	68.27	67.27	58.84
Crude protein %	14.00	13.50	13.00
Crude fat %	4.53	4.36	4.39
NEm mcal/cwt	93.10	92.24	94.63
NEg mcal/cwt	63.00	63.00	65.00
Calcium %	.60	.60	.60
Phosphorus %	.40	.38	.37

source as provided by the distiller's grain (modified distiller's grain is approximately 45% dry matter). The second TMR introduces an ensiled feedstuff, high-moisture ear corn; this provides a similar energy and protein level as TMR 1 but presents a lower pH feedstuff to the rumen microbes. The third TMR introduces another ensiled feedstuff, corn silage, which adapts the developing rumen to higher moisture and higher volume feedstuffs (Table 5).

A simple strategy to transition a calf from a grain mix to a TMR is shown here. The percentages are on an as-fed basis (Table 6).

As the calves are transitioned to the TMR, be mindful that 2.5% of the calf's body weight is a target for dry matter intake. To commence the transition, the calves should weigh 350 pounds (159 kg). If they are to consume 2.5% of their body weight on a dry matter basis, it translates into 8.75 pounds (3.98 kg). If an all-grain mix is fed, that would be 8.75 divided by 86% equaling 10.2 pounds (4.64 kg) as fed. Multiply 10.2 pounds (4.64 kg) X 75% to obtain 7.7 pounds (3.5 kg) of grain mix for step 1. If all the 8.75 pounds (3.98 kg) dry matter came from the TMR 1, divide 8.75 by 68% and obtain 12.9 pounds (5.86 kg) as fed. Multiply 12.9 pounds (5.86 kg) X 25% and obtain 3.2 pounds (1.45 kg) as fed; this may seem confusing at first, but after doing multiple calculations and correlating dry matter intake to "as fed" intake, it becomes understandable. Once the calves are completely on TMR 1, they will probably be about 400 pounds (181.8 kg) and eating 15 pounds (6.82 kg) of the TMR as fed. That is 400 pounds (181.8 kg) X 2.5% = 10 pounds (4.54 kg) dry matter. Divide 10 pounds (4.54 kg) dry matter by 68% to obtain 14.7 pounds (6.68 kg) as fed. The TMR 2 is to introduce the calves to an ensiled feedstuff, high-moisture ear corn. This TMR could be started once the calves weigh 475 to 500 pounds (216–227.3 kg) and fed until they weigh approximately 600 pounds (272.7 kg). At that time, they should be capable of eating approximately 28 pounds (12.7 kg) as fed of TMR 3. This diet can be fed until market weight. This assumes the calves are dairy or dairy crossbred calves. If the calves are straight beef calves, a different diet sequence may need to be implemented from 300 pounds (136.4 kg) body weight.

Table 6
Transition from dry grain–based ration to total mixed ration, percent of diet as fed

	Day 1–5	Day 6–10	Day 11–15
Grain mix	75%	50%	25%
TMR 1	25%	50%	75%

GROWER RATION STRATEGY FOR LIGHTWEIGHT REPLACEMENT HEIFERS

The following is a ration that is being used for dairy replacement heifers in a current facility. There are literally dozens of diet compositions that can be formulated, but this illustrates an example of what can be successfully fed to 400 pound (181.8 kg) dairy heifers that are being developed to 600 pounds (272.7 kg) before going to another facility where they will be grown and bred; this supports a growth rate of approximately 2.5 lb/d (1.14 kg/d) (Table 7).

It is important, when feeding lightweight, immature ruminants, to evaluate body condition and monitor dry matter intake. This monitoring, plus fecal consistency observations, will give an external indication of how well the rumen biome is adapting to the diet changes. During the stage from 200 to 400 pounds (91–181.8 kg) body weight, it is advisable to make daily dry matter intake increases of 0.5 to 0.75 pounds (0.22–0.34 kg) DM/head/day. Once an increase has been made, wait 3 to 4 days to make another increase and evaluate fecal consistency daily.

Stools from a calf with a well-adapted rumen should be light gold to light yellow with a formed pile that has a stiff pudding consistency (Fig. 4). If stools puddle out, or are watery, then the rumen is undergoing subclinical to clinical acidosis (Figs. 5 and 6).

Transit time from feed ingestion until it is completely out of the rumen is 35 to 48 hours but varies with the forage to concentrate ratio and the daily dry matter intake.[21] This is a continuum with portions of the feed passing out while new ingesta

Table 7
Replacement heifer total mixed ration fed from 400 to 600 pounds (ingredients expressed on a percent as-fed basis)

Ingredient	Replacement Heifer Diet
Grass hay	7.20
Corn silage	46.00
Cracked corn	9.00
Oats	20.00
Modified distiller's grain	15.00
Commercial 45% CP supplement	2.8
Nutrient analysis (DM)	
DM %	56.88
Crude protein %	13.80
Crude fat %	4.23
NEm mcal/lb	80.13
NEg mcal/lb	53.62
Calcium %	.63
Phosphorous	.39

Abbreviation: DM, dry matter.

Fig. 4. Stool that indicates a well-adapted rumen.

Fig. 5. Stool that indicates a rumen population under a pH challenge.

Fig. 6. Stool that indicates a rumen undergoing at least subclinical acidosis.

enter the alimentary tract and is significant when evaluating manure quality. If stools are loose, the intake event or ration change that caused it probably happened 2 to 3 days before the loose stools present. The looseness is caused by water being drawn into the digestive tract by osmosis due to fermentation products in the lumen of the intestinal tract. This is the response of the digestive tract to a nutritional insult.[22] This event, combined with an increased rate of passage, is how the digestive tract responds to rumen acidosis. From a management standpoint, keeping calves well bedded is important. It is impossible to implement a diet change to accommodate a small percentage of calves in a group with rumen acidosis. If clean dry bedding is accessible at all times, the animal can consume some fiber, which will generate saliva from mastication and help buffer the rumen.[22]

Weather events can trigger cattle to overconsume an available ration. Because cattle are usually fed in groups, it is difficult to observe which individuals have overconsumed their ration until the loose stools present. Looseness can also be triggered by offering more feed than the rumen is capable of fermenting or making an increase in energy too quickly or too great in magnitude. Increasing cattle 1 pound of dry matter (.454 kg) is the same as moving it up by 3 mcal NEg/100 pounds (45.45 kg) in a diet sequence. Making daily DM increases of no more than 1 lb/d (.454 kg) and then waiting 3 to 5 days before making another is advisable. It is also a good practice to increase NEg by no more than 3 mcal/100 pounds (45.45 kg) between diet changes. That is why animal and fecal consistency observation is critical to the management of a successful dietary regimen.

SUMMARY

Rumen development in young calves, 8 weeks to 400 pounds (181.8 kg), will be most successful if the first diet consumed promotes rumen papillae growth. This requires a diet that promotes butyric and propionic acid production. Grain-based diets promote

butyrate and propionate production, whereas forage-based diets promote acetate production. When the calf reaches 350 pounds (159 kg), additional protein sources and higher moisture feeds, such as modified distiller's grains, can be introduced to the diet. As dry matter intakes build and the calf matures, ensiled feedstuffs such as high-moisture ear corn can be introduced. And finally, the next step to diet sequencing is to introduce a high-moisture, high-volume feedstuff, such as corn silage to the diet. Observing manure quality and consistency is an important tool to evaluate rumen microflora adaptation to diet changes. Be mindful that it may take up to 48 hours for a complete rumen turn over regarding daily feed intake. Degradation in stool quality can be the result of an event or nutritional insult that took place 24 to 48 hours before the stool change presents.

DISCLOSURE

The author has nothing to disclose.

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