Nutrition for pre-weaned calves has been the subject of considerable change in recent years. The adoption of full potential milk diets – feeding calves at least 2.5 pounds of dry matter per day – is an increasingly popular practice.

Delivering this level of nutrition has been shown to improve calf growth and positively influence first-lactation milk production. But questions also arise regarding how this type of feeding could impact calf health, including:

- Can very young calves effectively absorb high levels of nutrition?
- Does feeding a full potential diet cause a higher incidence of scours?
- Does feeding high levels of milk solids suppress starter-grain intake?
- Does a full potential diet impact sickness incidence in the pre-weaned phase?
- Does this approach to nutrition affect sickness incidence in the post-weaned phase?

These questions have been explored by prominent dairy calf researchers in a number of recent studies. Their findings shed light on the comprehensive impact of feeding pre-weaned calves a full potential diet.

### Ability to absorb nutrients in young calves

A common question regarding full potential feeding is whether very young calves are physiologically prepared to process the nutrients such a program delivers. Theoretically, if they were not, accumulation of liquid feed in the lower gastrointestinal tract could provide a medium for pathogenic organisms to thrive, resulting in enteric disease.

Researchers at Texas Tech University conducted a study to explore this issue. A group of 12 newborn Jerseys calves were assigned to a low plane of nutrition (LPN) group (daily 2X feedings totaling 14.5 g DM/kg bodyweight of 20:20 milk replacer) or a high plane of nutrition (HPN) group (daily 2X feedings totaling 20 g DM/kg bodyweight of a 28:20 milk replacer). Daily blood samples of every calf were evaluated for plasma glucose and urea nitrogen concentrations, and fecal scores were assessed daily as well. The study was confined to the first week of life. The results showed:

- The calves fed HPN had higher fecal scores (indicating looser stools), but there was no difference in the dry matter content of feces between the two groups.
- The HPN calves had higher average daily weight gain throughout the study.
- There was no difference between the two groups in the percentage of energy intake that was captured as metabolizable energy, which averaged 88% across treatments.
- Thus, all calves in the study were able to absorb the nutrients provided, with the HPN group absorbing more total nutrients.
- The additional energy and amino acids absorbed by calves in the HPN group translated into greater lean tissue development and bodyweight gain.
- Fecal scores are not an appropriate measure of enteric health.

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3. Yu Liang, Jeffery A. Carroll, and Michael A. Ballou 2016 The digestive system of 1-week-old calves is well suited to incorporate protein & energy into tissue growth even when calves are fed a high plane of milk replacer J. Dairy Sci. 99:1929-1937.
Digestive health response to full potential diet

A University of Minnesota study evaluated the health of more than 10,000 calves raised in automatic calf feeder systems. The study included calves from 38 Midwestern farms, which were visited every 60 days for 18 months.

Calves were assigned health scores, which included evaluation of attitude; secretions from the ears, eyes and nose; and cleanliness of the rear end as an assessment of diarrhea. Their findings included:

- 58% of the diarrhea scores were normal; 32.4% indicated loose feces; and 9.4% indicated watery diarrhea.
- Each liter increase in peak milk allowance was associated with an 11.6% decrease in odds of higher diarrhea incidence. In other words, calves allowed more liquid nutrients had less scours incidence.
- Allowing peak milk consumption earlier in the calves’ lives also correlated with less diarrhea.

Response to scours challenges in pre-weaned calves

Intentionally exposing calves at different feeding levels to scours-causing organisms was the basis of two studies to evaluate the relationship between nutrition and health.

A Cornell University study evaluated the effects of exposure to Cryptosporidium parvum. Twenty Holstein bull calves were assigned to one of two feeding groups:

1. Conventional nutrition (CN): 0.13 Mcal intake energy/kg metabolic bodyweight using 20:20 milk replacer; or
2. High plane of nutrition (HPN): 0.30 Mcal intake energy/kg of metabolic bodyweight using 28:20 milk replacer.

All calves were inoculated with Cryptosporidium parvum oocysts at 3 days of age. Fecal health scores, oocyst counts, weight gain, dry matter intake and blood variables were evaluated for 21 days thereafter. Their findings showed that, compared to the CN group, the HPN calves had:

- Reduced duration of scours
- Greater hydration
- Higher average daily gain; and
- Improved feed efficiency.

A study at Texas Tech University evaluated the nutrition-health relationship in calves challenged with the scours-causing pathogen Citrobacter freundii. Twenty colostrum-fed Jersey calves were assigned to one of two feeding groups:

1. LPN: 0.88 lbs DM/day of 20:20 milk replacer for one week, followed by 0.99 lbs DM/day until weaning; or
2. HPN: 1.32 lbs DM/day of 28:20 milk replacer for one week, followed by 1.54 lbs DM/day until weaning.


6. Liang, Yu, Carroll, J.A., Ballou, M.A., Texas Tech University, Department of Animal and Food Sciences, Lubbock, TX, USDA-ARS, Lubbock, TX, Plane of milk replacer nutrition influences the resistance to an oral Citrobacter freundii opportunistic infection in Jersey calves at 10 days of age, American Dairy Science Association Annual Meeting 2015, #W352.
All calves were challenged with an oral dose of *Citrobacter freundii* on Day 10 of life. Feces and blood samples were analyzed regularly until 24 days of life, when calves were euthanized and their digestive organ tissue analyzed. Findings included:

- HPN calves had greater fecal scores, but there was no difference in dry matter percentage of feces between treatments.
- The HPN calves had greater water intake after the bacterial challenge.
- Rectal temperatures after the challenge were greater among the HPN calves.
- Overall, the HPN calves had a greater acute phase response to the bacterial challenge, indicating a higher level of immunity to overcome the disease challenge.
- These data reiterate that fecal scores should not be the only measure of enteric health, especially when evaluating the health effects associated with plane of nutrition.

### Post-weaning respiratory health of calves fed different planes of nutrition pre-weaning

Researchers at Texas Tech University conducted a study evaluating the effect of feeding a higher plane of nutrition in the pre-weaning phase on the ability of post-weaned animals to tolerate challenges with respiratory disease pathogens.

In the study, 30 male Holstein calves were enrolled into one of two feeding groups, either a restricted-quantity diet or a diet supplying 2.5 times more nutrients:

1. **LPN**: 0.98 lbs DM/day of milk replacer from birth to weaning; or
2. **HPN**: 1.83 lbs DM/day for 10 days, followed by 2.38 lbs DM/day until weaning.

After weaning, calves were challenged on day 81 with a nasal inoculation of bovine herpesvirus-1, followed by an inoculation on day 84 of one of three dosage levels of *Mannheimia haemolytica*. The results showed:

- The LPN calves were found to have higher mortality (4 of the 15 calves died, compared to 0 in the higher-nutrient group) and the LPN calves had greater measures of systemic inflammation.
- The HPN calves had significantly higher bodyweight at 70 days of age compared to the LPN group (179 vs. 137 lbs).
- Although HPN calves consumed more starter grain during the disease challenge, there was no significant difference when starter consumption was measured per pound of bodyweight.
- Calves receiving the highest bacterial challenge had the greatest increase in rectal temperature in the HPN group, but the lowest increase in the LPN group.
- Measures of inflammation indicated the LPN calves responded more severely to the combined viral-bacterial respiratory challenge.
- In all animals, greater doses of *Mannheimia haemolytica* increased the acute inflammatory response and prolonged inflammation.
- The most severe reactions were expressed by the LPN groups in all three challenge-dose groups, and all calves at the highest challenge level.

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7. Sharon, K.P., Liang, Y.L, Burdick Sanchez, N.C., Carroll, J.A., Broadway, P.R., Balicic, M.A., Department of Animal and Food Science, Texas Tech University, Lubbock, TX, USDA-ARS, Livestock Issues Research Unit, Lubbock, TX, Pre-weaning plane of nutrition and *Mannheimia haemolytica* dose influence metabolic responses to a combined bovine herpesvirus-1 and *Mannheimia haemolytica* challenge in post-weaned Holstein calves, American Dairy Science Association Annual Meeting 2015, #27.

8. Sharon, K.P., Liang, Y.L., Burdick Sanchez, N.C., Carroll, J.A., Broadway, P.R., Balicic, M.A., Texas Tech University, Department of Animal and Food Sciences, Lubbock, TX, USDA-ARA, Livestock Issues Research Unit, Lubbock, TX, Pre-weaning plane of nutrition and *Mannheimia haemolytica* dose influence metabolic responses to a combined bovine herpesvirus-1 and *Mannheimia haemolytica* challenge in post-weaned Holstein calves, American Dairy Science Association Annual Meeting 2015, #W26.
Post-weaning response to Salmonella enterica challenges

Texas Tech University researchers also published a summary of a two-part study that compared the performance of calves at two levels of nutrition, and evaluated the influence of pre-weaning plane of nutrition on a post-weaning challenges with Salmonella enterica. In the first experiment, 46 newborn Jersey calves were assigned to one of two diets:

1. LPN: 0.90 lbs DM/day with a 20:20 milk replacer; or
2. 1.34 lbs DM/day of a 25:28 milk replacer for 2 weeks, followed by 1.6 lbs DM/day for an additional 4 weeks.

All calves were evaluated for measures of immunity, fecal scores and bodyweight gain.

In the second experiment, 20 of those calves were challenged at 80 days of age with an oral dose of Salmonella Typhimurium. The results included:

• Pre-weaning average daily gain and feed efficiency were higher for the HPN calves.
• The LPN calves had a higher level of systemic inflammation pre-weaning, as evidenced by greater neutrophil expression of L-selectin.
• The HPN calves had a greater incidence (87.5% vs. 45.5%) and duration of days with high pre-weaning fecal scores.
• Following the bacterial challenge, starter grain intake was higher for the HPN calves.
• The HPN calves demonstrated a stronger immune response to the Salmonella challenge, as measured by percentage of neutrophils producing an oxidative burst in the days immediately post-challenge; intensity of the oxidative burst; and secretion of tumor-necrosis factor-α.

More to learn

Calf research on feeding calves higher levels of nutrients has shifted. The focus has moved from determining whether or not the practice improves calf growth, to how this feeding approach can potentially impact long-term animal health and performance. While more studies will add to this knowledge, the collective conclusions that can be drawn from the current body of nutrition-health research are:

Calves are able to absorb and process high levels of nutrients, even at very young ages.
• Feeding calves at a higher plane of nutrition may result in looser stools, but this is not necessarily an indication of clinical scours, and should not be used as the sole enteric health evaluation criteria.
• Calves fed a high plane of nutrition may consume less starter grain initially, but will likely have higher bodyweights and average daily gain at the time of weaning. When challenged by disease, calves that were fed more nutrients maintained better appetites and consumed more starter grain than their lower-fed counterparts.
• Supplying more nutrients to pre-weaned calves appears to equip their immune systems with greater ability to respond to disease challenges, both before and after weaning.